Reasoning, imagery and imagination in autism.

Scott, Fiona Jane

REASONING, IMAGERY, AND IMAGINATION IN AUTISM

FIONA JANE SCOTT

PhD

INSTITUTE OF PSYCHIATRY, DE CRESPIGNY PARK, LONDON, SE5 8AH

ABSTRACT

This thesis explored three areas in autism: (1) to test whether children with autism fail traditional theory of mind tasks due to a deficit in complex reasoning; (2) to confirm if children with autism are capable of veridical mental imagery; (3) to further explore imagination in autism.

Experiments 1 - 3 explored three areas of reasoning: transitive inference, analogy, and counterfactual syllogisms. Results showed no significant differences between children with autism and VMA-matched clinical controls across these three areas of reasoning. However, Experiment 3 also included an imagery condition where results demonstrated a cross-over in performance for children with autism versus controls, with the autism group performing better than controls without imagery but worse when imagery was introduced, whereas controls performed better with imagery and worse when no imagery was involved.

Experiments 4 - 7 further explored both veridical and non-veridical (imagination) imagery in children with autism and VMA-matched clinical and normal controls. Findings suggest intact veridical imagery in autism, but a significant deficit in non-veridical imagery compared to both control groups. Experiment 8 tested whether findings could be explained by a lack of generativity in autism. Results suffered from floor effects, however.

Findings are discussed in relation to current theories of autism and possible future directions for research.

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TABLE OF CONTENTS

Page Numbers

Page Numbers

INDEX OF FIGURES & TABLES

Page Number

Chapter Two

Chapter Four

<u>**Page Numbers**</u>

CHAPTER ONE

Autism and Current Hypotheses

1.1: Autism - The Diagnosis

Autism was first described by Leo Kanner in 1943, when he noted a specific cluster of symptoms present in certain cases of children referred for psychiatric treatment. His observations led him to outline the basic features he saw as underlying the disorder, notably "autistic aloneness", and an obsessive insistence on sameness. These observations still apply to the diagnosis of autism today, although the criteria are perhaps more specific than when Kanner first described the symptoms. Today, the key types of behaviour as defined by DSM-IV (1994) and ICD-10 (1994) that relate to a diagnosis of autism are:

- abnormal social development and social relationships
- abnormal development in language and communication
- a restricted and repetitive repertoire of interests and activities, coupled with..
- a lack of imaginative activity

1.1.i: Abnormal Social Development

This includes behaviours such as *Aloofness*, where the child may not like to be touched, does not respond to approaches from others, and does not initiate contact with others; *Passivity,* where the child will allow him/herself to be touched, and will approach others if they want something (such as food), but behave perhaps more like a puppet, allowing themselves to be led, responding to questions, and never showing "normal" two-way interaction; and *"Odd"*, where the child will approach and interact, but in a very one-sided and unusual or inappropriate way (for example, approaching strangers in the park and tugging their hair) (see Wing and Attwood, 1987). Children with autism tend to exhibit one or other of these abnormal social behaviours, to varying degrees, although the behaviour may not always be as clearly defined as reported here.

Joint Attention in Autism - Children with autism also show abnormal use of eye-contact, and a lack of joint-attention (where two or more people direct their attention to the same object or event - i.e., are sharing a common perception) and turn-taking. For example, Baron-Cohen (1989a) tested children with autism and matched controls on their understanding of "protoimperative" and "protodeclarative pointing". *Protoimperative pointing* is defined as the act of using the pointing gesture to indicate that you want something, (for example pointing to the biscuit tin if you want a biscuit.) *Protodeclarative pointing,* on the other hand, is defined as using the pointing gesture to indicate something that you wish to share interest in with another person, (such as pointing to an brightly painted car to express your interest and draw other peoples' attention to it.)

Baron-Cohen (1989a) showed that children with autism were quite good at comprehending protoimperative pointing, with 70% of the group with autism understanding that the experimenter was asking for a particular toy when he pointed to it. However, only 10% of the children with autism showed an understanding of protodeclarative pointing, realising that when the experimenter pointed at an aeroplane through the window (which was visible to the experimenter but not the subject from that angle), for example, he was trying to get the child to look at the aeroplane, or trying to *share attention.* Baron-Cohen also noted that whereas 40% of the group with autism produced examples of protoimperative pointing, none of the group produced any examples of protodeclarative pointing.

These findings support an earlier study conducted by Curcio (1978) who recorded the productions of protoimperative and protodeclarative gestures by 12 mute children with autism. He observed that whereas all the children produced examples of protoimperative actions, only 5 produced anything that could be possibly described as protodeclarative - and these examples were not to share attention, but to satisfy a need on the part of the child. In addition, when the children participated in protoimperative gestures less than half of them were observed to look at the person to whom the gestures were presented, and 5 of the children used the teachers hand as a tool, leading it to what they wanted.

In another study exploring joint attention behaviour Phillips, Baron-Cohen, and Rutter (1992) demonstrated that whilst 100% of normally developing infants aged 9-18 months would look at an adult's eyes if the adult performed an ambiguous action (such as offering an object then teasingly withdrawing it when the child reached for it), young children with autism did not tend to use eye-contact to try and disambiguate such actions: less than 11% directed their attention to the adult's eyes.

An earlier study of joint-attention behaviours in children with autism was reported by Mundy, Sigman, Ungerer, and Sherman (1986; 1987). They video-taped sessions between child and experimenter, where the experimenter presented toys to the child, pointed to posters, tickled the child, and engaged in a variety of social and turn-taking activities. Findings demonstrated that whereas the child would look at the experimenter following tickling, for example, they demonstrated little evidence of referential looking - between the experimenter's eyes and the object of interest - and rarely showed objects to share the experience.

Emotion in Autism - Individuals with autism also exhibit a lack of empathy, and tend to show little or no reaction to another person's pain or distress, or a seeming disregard for people who may be in their path (for example, walking over someone sunbathing in the park if they are in a direct line between the child with autism and the ball they are after). Sigman, Kasari, Kwon, and Yirmiya (1992) examined the behaviour of young children with autism and mental-age-matched matched controls when an adult pretended to have hurt herself, to be afraid, and to be very ill. They found that in every case the children with autism rarely looked at the adult, or attempted to relate to her in any way, whilst the control children frequently looked at or approached the adult.

Related studies have suggested that children with autism may have a deficit in the processing of emotional expression in others. Weeks and Hobson (1987) presented children with autism and controls with a set of photographs of people and asked them to sort them into groups that "go with" one another. The photographs showed a mixture of males and females, with a variety of basic emotional expressions (e.g., happy, sad, angry), some wearing hats, some with glasses on, some young and some old, and so-on. They found that 10 of the 15 control children sorted according to emotional expression before they sorted according to hats, whereas only 3 out of 15 children with autism did so. There was no difference in the overall ability of the children with autism to discriminate between the photographs, however, so this finding could not have been due to a generally worse sorting performance. Note that Weeks and Hobson (1987) found that the subjects with autism *could* sort by emotion when instructed to do so, they simply did not do so spontaneously. Baron-Cohen, Spitz, and Cross (1993) also found children with autism could sort photographs of happy and sad expressions in line with their mental age.

There is also some evidence to suggest that children with autism are less able to produce accurate examples of emotional facial expression themselves when instructed to do so (e.g., Langdell, 1981; Macdonald, Rutter, Howlin, Rios, LeCouteur, Evered, and Folstein, 1989). However, the experiments mentioned above may be confounded by evidence that children with autism have a specific deficit in face-processing, especially in recognising the mentalistic significance of the eyes (e.g., Baron-Cohen, Campbell, Karmiloff-Smith, Grant, and Walker, in press), and a deficit in imitation (e.g., Sigman and Ungerer, 1984; Ohta, 1987; Hammes and Langdell, 1982). The latter especially could lead to poor performance on tasks that require spontaneous imitation of emotions. Nevertheless, evidence does suggest a degree of abnormality in emotion-perception by children with autism.

Social Relationships in Autism - A further related abnormality in social behaviour is the lack of a general interest in social relationships. As has been described above, many children with autism exhibit this blatantly in their behaviour and are totally withdrawn, disliking physical contact of any kind. Lord (1984) studied the behaviour of 6 children with autism in a play-setting with other non-autistic children. She found that none of the children with autism initiated contact with other children more than four times in a fifteen minute period, and they responded to less than 25% of the attempts by the other children to interact. In addition, 5 of the 6 children with autism would not play co-operatively with others, and the majority showed evidence of actively avoiding the other children.

However, other studies have shown that this lack of interest in social relationships is not due to an inability to *understand* basic social relationships. Baron-Cohen (1991a) tested children with autism on their understanding of the relationships: (a) mother-child, (b) father-child, (c) peer, and (d) husband-wife. He found that children with autism had no difficulty in matching and understanding such relationships. Other experiments reported in that paper suggested that children with autism also had no difficulty in distinguishing animate and inanimate objects, and in understanding simple reciprocity. These findings suggest that the poor interest and participation in social relationships exhibited by children with autism is due to some other factor than simple understanding of such relationships.

1.1.ii: Abnormal Communication

This can either be apparent in the child having no language at all, or having some degree of language with unusual features. Abnormalities include *echolalia,* where the child will repeat phases or words spoken to him/her; lack of understanding of the *pragmatics* of language, such as taking a request (e.g., "Can you pass the salt?") as a literal question and responding, "Yes" (Frith, 1989, pp.121); a related inability to use and understand *metaphor*; and an abnormal use of *pronouns* (e.g., using "you" instead of "I", see e.g., Baltaxe, 1977).

Studies of language in people with autism have shown that abnormalities are not exhibited in every aspect of language, but rather are generally related to the meanings and social uses of language. Bartak, Rutter, and Cox (1975) demonstrated that high-functioning children with autism did not exhibit serious problems with word articulation, for example, but did produce a high proportion of echololic speech and stereotypical utterances, as well as having difficulties with personal pronouns, compared to children with a language disorder. Other research has provided evidence of abnormalities in the rhythm and intonation of language and speech - where the subject with autism will often speak in a monotonous fashion, for example, without the fluctuations of speech that are used in normal language for emphasis and expression of subtle meanings (e.g., Provonost, Wakstein, and Wakstein, 1966).

In exploring the understanding of meanings in language, much research has been conducted into the ability of people with autism to recall words and sentences, in order to explore whether they show the facilitation of recall that is evident in normal development when the material to be recalled is presented in a semantically connected - and therefore meaningful - way. Hermelin and O'Connor (1967) presented children with autism and children with mental handicap with sentences to recall. Some of the sentences presented common words in a meaningful way (e.g., "The bird builds its nest"), some presented common words in a meaningless, random way (e.g., "Home give down red fall"), whilst some were meaningful but with uncommon words (see Hobson, 1993, p.167). Hermelin and O'Connor found that the children with autism performed as well on the random, meaningless sentences as on the meaningful sentences, and in general performed better than the children with mental handicap. The latter group, however, performed far better with recall of meaningful sentences. Such a finding seems to support the hypothesis that children with autism have a deficit in processing the meaning of words.

Frith (1970) demonstrated that when presented with nonsensical sounds (e.g., ric - mut), children with autism and mental handicap controls performed equally as well on recall, but the performance by the children with mental handicap was improved if presented with meaningful sequences. Again, this suggests that whilst non-autistic subjects benefit from the meaning of language in recall, children with autism do not exhibit that benefit.

Tager-Flusberg (1991) also demonstrated that children with autism show a deficit in performance for recalling semantically related word lists, but she found that prompting helped the children with autism as much as control subjects - suggesting that the meaning of the words *was* being encoded by the children with autism, but they were less able to utilise that information in retrieval. The evidence overall clearly demonstrates an abnormality in the usage of language by people with autism, particularly involving the social and semantic aspects of language.

Non-verbal Communication - As well as the abnormalities present in the spoken language of children with autism, there are also abnormalities in non-linguistic communication, such as abnormal use of gestures and a lack of imitation. For example, Bartak, Rutter, and Cox (1975) found that children with autism were less able to use gestures to mime actions or to show the use of objects. As was mentioned earlier, children with autism also show abnormalities in the use of the pointing gesture (e.g., Curcio, 1978; Baron-Cohen, 1989a). However, some findings have suggested that children with autism are comparable to mental-age-matched controls on their usage and understanding of certain kinds of gestures, and only show abnormality in the use and understanding of socially-related gestures. Attwood, Frith, and Hermelin (1988) found that children with autism were able to understand and to produce *'instrumental gestures'*, such as putting a finger to the lips to say "Hush, quiet", or curling the forefinger at someone to indicate "Come here", but were deficient in their production and understanding of *'expressive gestures'*, such as hiding ones face behind your hands to indicate embarrassment, or putting an arm around someone to demonstrate friendship.

Similar findings can be seen in the study of imitation in autism, as was mentioned earlier when exploring the emotion-perception of children with autism (e.g., Ohta,

1987) with many of the imitative behaviours that are deficient in autism being related to social and interpersonal interactions. However, there is also evidence of a paucity in imitative abilities as relates to body imitation. DeMyer, Alpern, Barton, DeMyer, Churchill, Hingtgen, Bryson, Pontius, and Kimberlin (1972) found that children with autism were worse than controls at nose-touching, peek-a-boo, standing on one leg, touching a finger to the thumb, and so-on. Sigman and Ungerer (1984) also found evidence of general deficits in imitation of actions, such as banging a hammer, whilst Wing (1969) found that young children with autism exhibited difficulties in imitating movements. However, a recent paper by Charman and Baron-Cohen (1994) suggests that children with autism are intact in their ability to produce procedural (actions on objects) and gestural imitation at a basic mental-age appropriate level, and that imitation may be developmentally delayed but not wholly absent in children with autism.

Thus, it is apparent that children with autism have many deficits in both verbal and non-verbal communication, the majority of which appear to relate to the underlying social deficits present in autism, but some of which cannot easily be explained as secondary to such a deficit and stem perhaps from other cognitive functioning problems (see Tager-Flusberg, 1981; Baron-Cohen 1988 for overviews).

1.1.iii: Repetitive Behaviours and Restricted Imagination

A final aspect of symptomatology common (but not necessarily exclusive) to children with autism is the frequent occurrence of repetitive, stereotyped behaviour, and the arguably related lack of imaginative ability. Repetitive behaviours can vary from rocking movements and self-mutilation, to tearing up little pieces of paper for hours on end, both of which are extreme forms of repetition. However, not all children with autism are as extreme as this, and many show instead a tendency towards set routines or obsessive and unusual interests. For example, children with autism are often distressed if a certain order is not followed each day, such as having orange juice before cornflakes at breakfast, or always having to ask a set of precise questions every time someone new comes into the room. Also, children with autism will often have obsessive interests such as memorising the number of every lamppost in the street, or every bus-route in the city (see Frith, 1989; Baron-Cohen and Bolton, 1993; for overviews).

Research has suggested that there is a deficit in the ability to plan actions in children with autism (e.g., Ozonoff, Pennington and Rogers, 1991; Hughes, Russell, and Robbins, 1994) which may underlie such repetitive, obsessional behaviour. There is also evidence that children with autism do not exhibit pretend play behaviour, unlike normally developing and mentally handicapped children, (e.g., Leslie, 1987; Ungerer and Sigman, 1981; Gould, 1986; Baron-Cohen, 1987; Lewis and Boucher, 1988) thus leading to "uncreative" and unimaginative play, which might also relate to aspects of their obsessive and unusual interests. If you are unable to play imaginatively, then what else can you do other than memorise factual things, or follow a strict routine that does not require creative and original thinking? However, the relationship between imagination and obsessional behaviour is far from being understood.

1.1.iv: Age of Onset

Both the American system for diagnosis (DSM-IV, 1994) and the system employed by the World Health Organisation (ICD-10, 1994) lay down the key behaviours that are necessary for a diagnosis of autism. ICD-10 specifies that all key behaviours should be present before 3 years of age for autism to be diagnosed, whereas DSM-IV simply specifies that age of onset should be noted. Because of the nature of the disorder, it is at present difficult to diagnose autism with certainty before about 2 years of age, although work is under way at present on a system that may enable clinicians to predict a later diagnosis of autism from a very early age (Baron-Cohen, Allen & Gilberg, 1992; Baron-Cohen, Baird, Swettenham, Nightingale, Morgan, Drew, and Charman, in press).

1.1.v: Epidemiology and Related Factors

Autism has been shown to be present in all social classes, and across all cultures. The incidence of autism is about 2 and 4 children in every 10,000 (Wing and Gould, 1987), with a sex ratio of around 4:1, male to female. Approximately two-thirds of children with autism also have below average intelligence, and autism is often associated with other disorders including epilepsy, Fragile X syndrome, Tuberous Sclerosis, and various congenital anomalies. Such associations suggest a biological basis for the disorder. The belief that autism has a biological basis is perhaps further strengthened by the fact that children rarely grow out of autism when they reach adulthood. The vast majority of people with autism will have autism throughout their lives, although sometimes a certain degree of improvement is seen in social and communication abilities, for example. Finally, the biological theory of autism is supported by evidence of both brain damage (see review by Frith, 1989) and family genetic studies (Folstein and Rutter, 1977).

1.2: Current Theories in the Cognitive Development of Autism

1.2.i: Theory of Mind

One of the main psychological theories of autism is that children with autism have a deficit in the development of a *theory of mind* (Baron-Cohen, Leslie & Frith, 1985). The term "theory of mind" was coined by Premack and Woodruff (1978) whilst they were studying deceptive behaviour in primates. Premack and Woodruff defined theory of mind as follows:

"In saying that an individual has a theory of mind, we mean that the individual imputes mental states to himself and others...such states are not directly observable, and...the system can be used to make predictions, specifically about the behaviour of other organisms." (p.515).

The rationale behind studying theory of mind in autism is that by utilising a theory of mind we are able to relate to other people, predict their behaviour, participate in complex social interactions, and understand communication flexibly. In order to appreciate someone else's distress for example - that is, to feel empathy, one needs to have some idea of what they may be thinking, and why. In order to recognise that someone is cheating at cards, one needs to recognise that the perpetrator has not been seen by the other players, that he is attempting to conceal his behaviour from them, and that he knows they would react in a certain way if they found out - anger, surprise, indignation, and so-on. In order to understand why someone says "Just drop it!", one needs to recognise they intend to speak figuratively, etc..

The examples given are simply to show the diverse nature of theory of mind use in everyday situations. To normal individuals, theory of mind understanding comes so automatically that we are unaware of using it consciously, for the most part. Because of the fundamental role this kind of understanding of mental states plays in everyday human social interaction, experimental study of theory of mind development in children with autism has become a fast growing area of psychological research.

Mental states include: knowledge, belief, intention, desire, attention, imagination, and pretence. Gopnik & Slaughter (1992) investigated the understanding of some of these mental states with a group of normally developing subjects, and consequently proposed a three-stage model of development for theory of mind in normal children:

Stage 1 - Pretence, perception, and imagination

Stage 2 - Desire and intention

Stage 3 - Knowledge and belief

Gopnik & Slaughter (1992) suggested that the mental states listed for Stage 1 are easiest to understand because they are nonrepresentational. This claim is open to debate, since Leslie (1987) suggests that in order to pretend one has to be able to "metarepresent", that is, form a mental representation of a representation. In addition, thus far imagination in young children has not been explored experimentally in great detail. However, research has suggested an definite progression in normal development of the understanding of different kinds of mental states, with children showing pretend play by around 2 years of age, understanding desires and knowledge by around three years of age, and understanding beliefs by four years of age (see e.g., Wellman, 1990; Perner, 1991; Leslie, 1987) although this developmental sequence awaits further testing (it is not known if it is invariant, for example).

Many of the original studies of theory of mind understanding in normal children explored false-belief understanding - a mental state that is listed by Gopnik & Slaughter at Stage 3 of their model, and thus thought to be one of the later mental states to be understood within theory of mind. False belief understanding (i.e., understanding that other people's beliefs may be different to one's own) has been explored in children using a variety of tasks.

Baron-Cohen, Leslie & Frith (1985) tested the ability of children with autism to understand false belief, using a task that had been used in theory of mind testing of 3 and 4 year old normal children by Wimmer and Perner (1983). The task utilised by Baron-Cohen, Leslie & Frith (1985) was called the Sally-Anne experiment, and is outlined below.

The Sally-Anne Experiment

The child is first introduced to two dolls: Sally, and Anne. Sally has a marble, which she places in her basket. Anne has a box. Sally then decides to go out for a walk. While Sally is absent, Anne takes the marble out of Sally's basket, and puts it into her own box. Sally then comes back, and the child is asked "Where will Sally look for her marble?"

Normally developing 4 year old children, and children with Down's syndrome are able to make a successful inference, and conclude that Sally will look in the basket. However, around 80% of children with autism are unable to draw the correct conclusions, even though they are of an appropriate verbal mental age, and even though they can answer control questions concerning where Sally put the marble in the first place, and where the marble is now.

This initial exploration of theory of mind understanding in children with autism has since been supported by numerous studies (e.g., Leekam and Perner, 1991; Sodian and Frith, 1992; Baron-Cohen, 1989b;1989c;1991b; Leslie & Frith, 1988; Phillips, 1993) giving credence to the hypothesis that there is a specific impairment in the understanding and application of a theory of mind by children with autism. For example, Perner, Frith, Leslie, and Leekam (1989) conducted a test of false-belief understanding using a task known as the "Smarties Test". Here, the child is shown a sweet container and is asked what they think is inside. Children all say "Sweets" or "Smarties", and are subsequently surprised to find that the container only holds a pencil. The child is then asked what another classmate (who had not been present) would say was in the closed container. Normally developing 4 year old children, and children with Down's syndrome, are able to correctly respond that the classmate would say "Smarties" or "Sweets" because they had not seen the true contents of the container. Children with autism, however, tended to say that the classmate would say "A pencil", even though they knew that the classmate had not seen inside the container.

Flavell, Green, and Flavell (1986) demonstrated that four year old normally developing children could understand the distinction between appearance of an object and it's real nature, and how this affects their own beliefs. For example, when presented with a sponge that looks like a rock, the child would say it is a rock. When allowed to handle it, the child would then say it is *really* a sponge, but it *looks like* a rock. Normal children can recall their own past false-belief - that they thought it was a rock - as well as holding in mind both a representation of reality (it is a sponge) and a representation of false appearance (it looks like a rock). Baron-Cohen (1989b) adapted this study and presented it to children with autism and matched controls. He found that after saying a pretend chocolate bar looked like chocolate, then touching it and finding it was plastic, children with autism persisted in saying that it looked like chocolate and it *really was* chocolate, whereas the control groups could correctly say it looked like chocolate but it was really plastic. This finding demonstrates the difficulty children with autism have in holding in mind two different representations at the same time that are both 'true' for a single scenario. Clearly this relates to difficulties with the Sally-Anne test of false-belief, where the child needs to represent the real state of affairs at the same time as a false state of affairs that is 'true' for another protagonist.

Sodian and Frith (1992) explored understanding of deception versus sabotage by children with autism. They presented subjects with a box and padlock, and asked them to put a sweet (a "smartie") inside the box. Children were then instructed either to help a "nice smartie friend" to find the sweet, or stop a "nasty smartie eater" from finding it. In the Sabotage condition, the children could decide whether or not to padlock the box, depending on which puppet - "smartie friend" or "smartie eater" - was coming. In the Deception condition, the children had no key for the lock. The puppet could not see if the box was locked or not, and would ask the child to tell them whether it was locked or open. Control subjects were successful at both sabotaging "nasty smartie eater" attempts to get the sweet by locking the box, and also deceiving him, by telling him the box was locked even though they had no key with which to lock it. Children with autism were comparable to controls on their performance of sabotage, but were significantly poorer at their ability to deceive. They tended to tell the truth to the nasty puppet, even though by doing so they would forfeit the sweet which they wanted to win for themselves. Sodian and Frith (1992) claimed that this demonstrated an inability to understand beliefs, in that they did not realise that the "nasty smartie eater" held a different belief to the child about the status of the box, or that his belief could be misled according to the information they supplied to him.

Research has also further explored the performance by those few children with autism who are successful in passing traditional false-belief tasks. Happe (1994) presented groups of subjects with autism - some who failed first-order theory of mind tasks, some who passed first-order theory of mind tasks, and some who could pass second-order (i.e. "Where does Sally think that Mary thinks the marble is?") theory of mind tasks - and control subjects with a battery of theory of mind tests, and naturalistic stories which required mental-state understanding. The stories included examples of jokes, pretense, figure of speech, white lies, double-bluff, persuasion, and so-on, with subjects being required to explain the actions of story characters. She found that children with autism who passed second-order theory of mind tests tended to perform better on the naturalistic stories than those who could not pass theory of mind tests, or who passed only first-order tests, but that these stories proved harder for the subjects than traditional tests of theory of mind. This finding suggests that traditional theory of mind tasks can predict performance in a more naturalistic context, and also that it may be possible to pass some theory of mind tests using a non-theory of mind technique, since many subjects who performed well with second-order false-belief were unable to understand white lies, jokes, and so-on. Happe (1994) suggested that findings may demonstrate the difficulty people with autism have in applying social knowledge in everyday life - without the salient cues such as are provided in theory of mind tasks, subjects with autism demonstrate their true inadequacy in understanding of mental states.

As well as exploring direct task performance on theory of mind, researchers have also studied understanding of mental state language. For example, Baron-Cohen, Ring, Moriarty, Schmitz, Costa, & Ell (1994) found that children with autism performed significantly worse than a matched group with mental handicap in their ability to recognise mental state terms from a list of words, whilst Tager-Flusberg (1989, 1992) found that children with autism spontaneously produced fewer cognitive state terms in their speech than did mental-age-matched non-autistic mentally handicapped controls.

Happe (1993) demonstrated that subjects with autism have a deficit in the understanding of metaphors - a finding that supports evidence of an inability to understand peoples intentions and mental states, outside findings from traditional theory of mind tasks. Failure to understand intention has also been demonstrated by Phillips (1994).

In addition, other related deficits including other mental states and associated understanding have been demonstrated. For example, Baron-Cohen (1989b) found that children with autism showed an abnormality in their understanding of thoughts, dreams, and pretense, as well as a lack of associating the brain with such mental acts (instead they would say the function of the brain was to make their legs walk, for example). These findings, along with those listed above, lend further evidence to the suggestion that the main deficit behind autism is abnormal development of a theory of mind.

The theory of mind deficit has also been termed a deficit in *"metarepresentation"* (Leslie, 1987; 1991), that is, in the ability to form a mental model (representation) of a representation. Leslie (1987) initially suggested that children with autism are capable of forming primary representations (mental models of something immediate to perception, such as a chair), but that they are unable to form a *"decoupled"* representation of that primary representation, a representation that is separated from veridical concepts and which can then be manipulated apart from reality - something which he argues is necessary for pretend play, for example, and which thus demonstrates that pretend play involves blossoming theory of mind ability. This hypothesis can be applied to many of the traditional tests of theory of mind, (for example, to understand that someone can hold a different belief to you, you need to be able to form the representation: Sally (agent) thinks (attitude) "the ball is in the basket", whilst also holding the representation: I (agent) know (attitude) "the ball is in the box".) Leslie's hypothesis has been modified and clarified in his more recent work (see e.g., Leslie and Roth, 1993; Leslie, 1994). In short, it is suggested that an agent actively holds an attitude towards the truth of a proposition. The situation described by the proposition can be reality, or a possibility, or an impossibility, but the agent's attitude to it's truth is always real - for example, Mary believed it was snowing. It is irrelevant whether or not the snow was real - what is important is Mary's attitude towards the truth of that proposition, since it is that attitude which guides behaviour. The "metarepresentational" capacity for considering various purely cognitive, and thus 'invisible', representations is what underlies behaviour, and the understanding of behaviour in others (see Leslie, 1994), and it is this ability to metarepresent which is argued to be deficient in autism.

The claims made by Leslie derive initially from an exploration of the lack of spontaneous pretend play observed in children with autism. By the age of 2 years, normally developing children are proficient at both producing and understanding pretense. However, children with autism show little evidence of pretense, even at a far greater chronological and mental age. For example, Ungerer and Sigman (1981) found that children with autism, compared to mentally handicapped non-autistic children, produced significantly less symbolic - or pretend - play, and were especially lacking in their play involving dolls. Instead they concentrated on functional play (that is, play that demonstrates knowledge of how something works, such as a toy car moving along the ground) or building towers of blocks, for example.

Wing, Gould, Yeates, and Brierley, (1977), in their study of the symptoms and features of autism, found that the lack of pretend play was a consistent feature in all the children diagnosed with full autism (i.e., not simply "autism-related behaviours"). This lack of pretense has been demonstrated frequently (e.g., Wulff, 1985; Mundy, Sigman, Ungerer, and Sherman, 1987; Baron-Cohen, 1987) and is recognised as a core feature for defining autism (Rutter, 1978; DSM-IV, 1994; ICD-10, 1994).

Findings such as these support the hypothesis proposed by Leslie (1987), since the production of functional play only requires a primary representation - you treat the object *as* the object it is - such as a car, for example. Pretend play often requires one object to be treated as if it were another - for example, pretending a banana is a telephone (Leslie, 1987, pp.416), or treating something that is absent as being present -

for example, pouring pretend tea from a teacup - abilities that Leslie argues require metarepresentation, and the *decoupling* of the pretend situation from reality. Thus, children with autism not only exhibit a lack of understanding of mental states, but also a lack of production and understanding of pretense - an ability that is present by two years of age in the normal child. Together with the other findings reported here, this is strong evidence for a deficit in theory of mind in children with autism.

1.2.ii: Executive Dysfunction Hypothesis

An alternative to the theory of mind hypothesis is that children with autism have a specific impairment in "executive function". The Executive Function is thought to be mediated by the frontal lobes, and includes inhibition of prepotent but inappropriate responses, planning, flexibility of thought and action, organised search, set maintenance, and impulse control (see e.g., Shallice, 1988; Baddeley, 1991; Ozonoff, Strayer, McMahon & Filloux, 1994). It has been suggested that some of the behaviours seen in autism are very similar to the behaviours seen in individuals who have suffered damage to areas of the frontal lobes of the brain. These behaviours include a tendency toward rigid and inflexible behaviour, and perseveration. People with autism also show evidence of being unable to inhibit inappropriate behaviours and responses to stimuli.

For example, Russell, Mauthner, Sharpe, & Tidswell (1991) presented children with autism, and matched clinical and normal controls, with a competitive task of strategic deception. Children were trained that it was in their interest to try and deceive the experimenter, because this would win them a chocolate. In the experimental phase, the child was shown boxes, one of which contained a chocolate. In the training phase, the child could not see the contents of the boxes whereas in the experimental phase the boxes had "windows" facing the child so that he/she could clearly see which box contained the chocolate. The two control groups quickly learned that to get the chocolate they had to lead the competitive experimenter to the empty box. The children with autism, however, perseverated in pointing to the box containing the chocolate, even though this meant they would lose the chocolate to the experimenter. Russell et al. suggested that the children with autism were failing because they were unable to inhibit their responses to the salience of the chocolate, and perseverated in their responses once they had started them. However, this experiment confounded a theory of mind component (understanding the beliefs and intentions of the competitor - see e.g., Sodian and Frith, 1992; Baron-Cohen, 1992) and an executive function component.

Hughes & Russell (1993) devised an experiment where the subjects' were presented with a specially designed box with a marble in the top on a ledge. The subject had to try and get the marble. The box had a built-in trap mechanism, which would be triggered when the subject reached for the marble, thus causing the marble to drop out of reach inside the contraption. After the subject had attempted to reach the marble several times, the experimenter demonstrated how to get the marble. This could be done either by (1) turning a knob on the box, or (2) flipping a switch on the other side. Coloured lights would signal when it was possible to use the knob-route, and when the switch-route had to be used instead. After both of these methods, and their corresponding signals, had been learnt by the subject, the subject was then again asked to try and get the marble.

Children with mental handicap, and normally developing controls, were both able to alternate their responses to use either the knob-route or the switch-route, depending on which signal was showing. The children with autism, however, perseverated in using the knob-route, even when the signal showed that that route was no longer available. Hughes & Russell claimed that this was further evidence that children with autism have difficulty inhibiting, or disengaging their attention from a salient but inappropriate response, even though in this case - unlike the "windows" task - there was no competition. This inability to inhibit inappropriate responses, and a tendency to perseveration, is thought to be due to an executive dysfunction.

Recent studies by Jarrold, Boucher & Smith (1993; submitted) have suggested that the lack of pretend play that is evident in children with autism can also be explained by executive dysfunction, as opposed to a deficit in metarepresentation. They attempted to elicit pretend play behaviour in children with autism using "props" and demonstrations (e.g., showing the child how to brush teddy's teeth, and asking the child to do the same whilst presenting pieces of dowel of various lengths to be selected for use as the "toothbrush".) Jarrold et al. argued that under these circumstances children with autism were capable of producing the required behaviour, and that the lack of pretend play usually found in children with autism is due to a *generativity* deficit. However, in such circumstances it may not be necessary to understand what one is doing; the task could be performed successfully simply by "intelligent guessing" (Baron-Cohen, 1989a).

There is, however, some doubt as to whether an executive dysfunction is specific to autism, since related behaviours are observed in a variety of disorders including conduct disorder (e.g., Lueger & Gill, 1990), attention deficit disorder (e.g., Chelune, Ferguson, Koon & Dickey, 1986; Grodinsky and Diamond, 1992), treated patients with PKU (e.g., Pennington, Van Doorninck, McCabe, and McCabe, 1985; Diamond, Hurwitz, EunYoung, Grover, and Chester Minarcik, in press) schizophrenia (e.g., Frith, 1992; Elliot, McKenna, Robbins, and Sahakian, 1995), Gilles de la Tourette Syndrome (e.g., Baron-Cohen, Moriarty, Mortimore, and Robertson, 1995; Bornstein, 1990; 1991), Parkinson's disease (e.g., Downes, Roberts, Sahakian, Evenden, Morris, and Robbins, 1989), and mental handicap (e.g., Borys, Spitz, and Dorans, 1982). Nevertheless, there remains evidence that there may be a problem in autism concerning executive function, and thus as a current hypothesis on the nature of the cognitive deficits of autism it warrants serious consideration.

1.2.iii: Weak Central Coherence Hypothesis

A third hypothesis that has emerged recently has been proposed by Uta Frith (1989). Frith suggests that children with autism have a deficit in "central coherence". That is, whilst they may be able to retain large amounts of information, they are unable to pool this information into a meaningful whole, and thus they deal with information as consisting of many segregated and unrelated pieces. Frith argues that in normal individuals a central system in information processing in the brain actively pulls together fragmented perceptions and stimuli in an attempt to discover the overriding meaning in that information. This central system "interprets, compares and stores. It draws inferences and reinterprets. It also initiates actions." (Frith, 1989, pp.97). She goes on to argue that this central processing system is weak, or abnormal, in children with autism. Evidence to support this conclusion includes the finding by Shah & Frith (1983) that children with autism exhibit superior performance on locating figures that are "embedded" in another picture, such as a tent shape that is part of an overall picture of a child's pram (see Karp & Konstandt, Children's Embedded Figures Test, 1971). Here, children with autism and controls were given a series of pictures showing schematic drawings of common objects, such as a pram, a rocking horse, and so-on. Beside each picture was a figure (for example, a triangular "tent" shape) that was a "hidden" component part of the overall picture. The subjects were required to locate the hidden figure within the overall picture. Shah & Frith argue that children with autism performed extremely well, being more accurate than non-autistic children of the same mental and chronological age.

In an earlier study (Frith, 1970) found that children with autism were as good at recalling random nonsensical strings of words (e.g., ruc - ruc - mit - ruc - mit - mit - ruc - mit) as recalling strings that followed a specific pattern (e.g., ruc - mit - ruc - mit - ruc - mit - ruc), whereas normal children and mental handicap controls are far better at recalling the patterned strings than the random strings.

Both of these studies arguably suggest that children with autism do not store information in the same way as other individuals, whether normally developing or mentally handicapped, and that they may instead store information in segregated parts rather than coherent wholes. This claim is reinforced by anecdotal evidence, such as children with autism being able to complete jigsaw puzzles that are upside down, and being adept at noticing very specific details (for example, seeing a thread on a patterned carpet).

Thus, Frith suggests that children with autism have weak central coherence, and that this leads to an inability to see meaning and structure in things, a tendency towards social aloofness, an inability to understand context, and also explains superior performances in tasks of Block Design, Embedded Figures, and rote memory.

This hypothesis may be quite closely related to the executive dysfunction hypothesis of autism, since executive function is said to include functions that mediate planning, organised search of information, and flexibility of thought - operations that may be difficult if information is not formed into meaningful chunks. Disentangling the Executive Function and Central Coherence theories will be important for future research.

1.2.iv: Simulation Deficit Theory

A final hypothesis that holds relevance to this thesis concerns the growing interest in "Simulation Theory" (e.g., Harris, 1991, 1993; Currie, 1994, 1995). Simulation Theory suggests that we interact with other individuals, and understand and predict their behaviours, via a kind of mental "acting out" of what we would do or feel if we were in their shoes. In other words, one takes on a role of sympathetic re-enactment, and applies general principles already known about how our society and environment operates, in order to imagine how someone else might feel or react. These simulated beliefs, thoughts and so-on are run " 'off-line', disconnected from their normal perceptual inputs and behavioural outputs" (Currie, 1994, pp.1) thus enabling the simulating individual to understand another's mental processes without being involved directly in the situation, or producing the related behaviours.

Proponents of Simulation Theory suggest that not only do we understand the thoughts, beliefs and desires of others via simulation, but that it is via simulation that we engage in pretend play, simulating to the best of our abilities and knowledge what it is like to be a superhero, or a highwayman. Simulation is also proposed as the explanation for other forms of mental imagery and imagination, which are suggested to be "side-effects" of the need for simulating our environment, as well as being a necessary requirement for planning routes and actions, and the reason for the experience of empathy when one sees films of starving children in Africa, for example.

Following this reasoning, it is clear why advocates of the Simulation Theory suggest that an impaired simulative capacity could explain the deficits seen in children with autism. It is suggested that a lack of simulation ability would make it hard for someone to begin to understand others' minds or develop normal social relationships, or to feel empathy for others, or understand pragmatics or metaphors.

It is also suggested that a lack of simulation abilities can explain the autistic tendency to be interested in very specific, constricted, factual topics, such as numbers of lampposts in the area, train timetables, and calendars. Simulation theorists claim that if one lacks imagination, a cognitive function that is vital to simulation, then one has no interest in imaginative topics, and therefore finds fascination in topics that are purely based on fact.

Simulation theorists also claim that being unable to simulate would explain the poor planning strategies exhibited by people with autism, since they would be unable to think out their actions and the various consequences in advance.

However, as yet there appears to be little empirical evidence to substantiate the claims made by Simulation Theorists, since much of their argument as relates to children with autism is based on theoretical analysis of other hypotheses and experiments. Some experimental work has been conducted by Harris (e.g., Harris and Muncer, 1988) where children with autism were shown to perform significantly worse than controls in understanding feelings of story characters who wanted different things and only one characters desire was satisfied. It is argued that these results are due not to a lack of theory of mind, but to "a failure to adjust the default setting" (see Harris, 1993, pp.297). Harris argues that when children imagine states of belief they do so against a background of default settings, and that these settings will remain operative unless they are overridden by the consideration of an alternative desire (Harris, 1993, pp.284). Children with autism fail to simulate situations accurately due to this lack of adjusting defaults, and thus fail to understand many social behaviours.

To date there is little evidence with which to evaluate the simulationist theory of autism. However, the arguments put forward theoretically do raise some interesting points and are considered during the course of this thesis. For a fuller review of the Simulation Theory see Chapter 5, and Currie (1994; in press).

1.2.v: Relations Between the Theories of Autism.

In the brief overview of current theories in the developmental psychology of autism one can see that two of the hypotheses concentrate for the most part on general information processing (the Executive Dysfunction hypothesis, and the Weak Central Coherence hypothesis), whereas the other two hypotheses (Theory of Mind and Simulation Theory) concentrate on a specifically *social* information processing, as being the basis for the abnormalities in autism. It is evident that there is a certain degree of overlap between all these theories, however. For example, some of the features described by executive dysfunction theorists, such as failure to inhibit a prepotent response and thus respond flexibly to a stimulus, could be seen as similar to aspects of Harris's arguments for simulation theory when children fail to consider alternative default situations - something which presumably requires flexible shifting of thought. There are certain similarities also between theory of mind metarepresentations of agents' attitudes towards situations and propositions, and simulation of someone else's thought processes, the main difference lying in the "chicken and egg" syndrome - which comes first, simulation or metarepresentation? Which is an offshoot of which? (Leslie and German, 1995, suggest that versions of simulation theory include aspects of metarepresentation, and are basically much the same argument but using different terms. This does not apply to the more stringent descriptions of simulation theory, however.)

Thus, although each developmental and cognitive theory sees itself as separated from the other competing theories, there are many similarities and overlaps between them. This is not unexpected, since each is attempting to explain the same cognitive processes and behaviours observed in autism, and it is possible that the truth will ultimately be an amalgamation of various theories. There are studies which support each theory, as well as studies which refute aspects of each theory. Since the ultimate aim of research in this area is to find the truth and understand the nature of normal and abnormal cognition, for the benefit of teaching, treatment, and so-on, it is important to test if some theories are undermined by critical studies, since according to Popper refutation brings us one step closer to the truth we seek. During this present study, data will be presented which refutes claims of some of the theories mentioned, and which supports claims of other theories mentioned. It is hoped that this will both further the knowledge about autism, and spark responses and criticisms from alternative theories.

1.3: Aims of the Thesis.

The primary aim of the experiments in this thesis was to explore *general reasoning* abilities by children with autism when presented with tasks that do not involve theory of mind understanding, yet which are arguably similar in the reasoning demands required. Traditional theory of mind tasks, such as the Sally-Anne test described earlier, not only require an understanding of other minds, but also require the ability to perform complex reasoning on the information presented. Thus, failure by children with autism on such tasks may be due to either a general deficit in complex reasoning abilities (related to executive dysfunction, or an inability to pool fragments of information into a whole), or a specific deficit in social reasoning abilities (related to lack of a theory of mind, or a problem in simulating what another person may be thinking). Reasoning has not yet been explored in any depth in autism. Therefore Experiment 1 aimed to further explore the claim that children with autism have a *specific* deficit in theory of mind understanding, by presenting them with "non-mentalistic" (but just as cognitively demanding) reasoning tasks.

The second aim of the thesis was to explore *imagery* abilities in children with autism. As has been previously mentioned, in order to pretend, or to understand the minds of others, one may need to form "mental models". The theory of mind hypothesis does not claim that these mental models are specifically "pictures in the head", but some form of mental imagery is often involved. Mental imagery in autism has been previously examined as it relates to mental rotation tasks (e.g., Shah, 1988), but there is very little other work on this topic. Mental rotation tasks require the subject to select a picture that depicts a stimulus object they have present before them from another angle, whilst ignoring other pictures which do not correctly portray the stimulus object. These tasks can arguably be passed without the need to form a *mental image* of an absent object, since the stimulus is always present before the subject.

The Sally-Anne task, however, requires the subject to form a mental image of a situation that is *not* before them - that is, the marble is in the basket, only in Sally's mind. In reality, the marble is in the box. This kind of mental image or mental model requires the subject to hold in mind two different situations, that are both "true" at one and the same time. In addition, in order to perform pretend play, one needs to be able to form a mental model where a banana can be a telephone, for example. This type of mental imagery may or may not be pictoral, but an exploration of visual imagery processes in children with autism is necessary to explore whether a lack of "metarepresentation" may be related to an inability to form certain kinds of mental images.

A final, and related, aim of the thesis was to explore *imagination* in children with autism. A lack of imaginative activity is one of the key features used to diagnose autism (DSM IV, 1994; ICD-10, 1994) and yet outside studies of pretend play, imagination in autism has not been explored per se. With paucity of imagination being so important for the diagnosis of autism, this area warrants more study than it has currently received.

In addition, as has been mentioned earlier, the Simulation Deficit hypothesis of autism relies solely on the assumption that individuals with autism have a deficit in imagination and/or imagery. As far as it *is* part of the diagnosis of autism, this is fine, but if a theory concerning their fundamental cognitive deficit is to be proposed on the basis of this postulated deficit, then it is of great importance to explore their imaginative capabilities experimentally, in a controlled way.

Thus, the thesis includes an exploration of: (1) General abstract reasoning processes in autism, (2) Visual imagery production in autism, and (3) Imagination in autism.

1.4: Brief Overview of the Thesis.

Chapter 2 outlines some of the methodological issues surrounding the studying of clinical populations, as well as summarising the details of the subjects who took part in the experiments reported in this thesis.

Chapter 3 reviews the relevant literature on reasoning, looking first at reasoning by normally developing children and adults, and then exploring findings from research into reasoning by children and adults with autism.

Following this review, Chapter 4 reports a series of three experiments exploring performance by children with autism and matched controls on various kinds of abstract reasoning tasks. Experiment 1 examines performance on a task of *transitive inferential reasoning*; Experiment 2 explores *analogical reasoning*; and Experiment 3 examines reasoning with *counterfactual syllogisms*. This third experiment also incorporates a condition requiring mental imagery, and/or imagination.

As stated, Experiment 3 involves the role of imagination in reasoning. To anticipate the results, this is the first point at which a deficit appeared. Therefore, the next area explored is that of imagination in children with autism. To introduce this, Chapter 5 gives a review of the relevant literature, investigating mental imagery and imagination in normal development, and in individuals with autism.

Chapter 6 follows this literature review with a series of experiments investigating *mental imagery* and *visual memory* in children with autism and matched controls. This aspect of the experiments conducted concentrates on mental imagery for factual and veridical things. Experiment 4 explores visual memory abilities in recalling stimuli presented on a chessboard, whilst Experiment 5 examines subjects' abilities to recall information presented in a set of complex colour pictures, as well as *how* that information is recalled.

The experiments on veridical mental imagery reported in Chapter 6, will be followed in Chapter 7 by a series of experiments on *non-veridical imagery* and *imagination* in children with autism and matched controls. Experiment 6 explores performance on a drawings task where subjects are required to draw both veridical and non-veridical representations of common items (houses and people). Experiment 7 elaborates on this and explores subjects abilities to draw real and unreal things, both spontaneously and under specific instruction. Experiment 8 examines generativity performance by subjects, to test whether a deficit in generativity could explain earlier findings.

The thesis finishes in Chapter 8 with a reminder of the original questions raised, a summary of the experimental findings of the thesis, and a discussion relating to those findings and their relevance to autism and to normal development. In addition, the discussion considers possible future directions for research in order to further explore some of the questions that are raised by the present findings.

CHAPTER TWO

Methodology and Subjects

2.1: Methodological Considerations

When research is conducted into the cognitive development of children with autism, the subjects with autism need to be matched with appropriate control subjects. Since the majority of the tasks explored in the present study were aimed at a level where four year-old normally developing children were successful (thus being a similar age to observed successes by normal children with theory of mind tasks), this subject group was a necessary control to observe differences between normal development and the development of children with autism.

However, normal children alone do not suffice as a control group. Children with autism often have various mental handicaps and learning difficulties alongside their autism, as mentioned in Chapter 1, and thus a second control group is required - one which is matched for mental age, and which includes subjects with various mental handicaps and learning difficulties, but which does not include subjects who have diagnoses of autism, or autism-type symptoms. This research design was pioneered by Hermelin and O'Connor (1970) and has been used successfully since then (Frith, 1989).

Also, since both the group with autism and the group with mental handicap were below the normal developmental level for their chronological age, these subjects needed to be selected for a matched mental age to normally developing subjects. In the studies reported here, children were selected according to their *verbal* mental age (VMA). This was chosen as the important criteria because it is a more conservative measure of ability for the tasks presented in the present study. Children with autism often exhibit a much higher non-verbal mental age (NVMA) for tasks such as Block Design, and Raven's Progressive Matrices, than their VMA. If children had been selected according to their NVMA, they may have failed the tasks presented due to poor understanding of instructions, and other language-related problems such as lack of speech, or difficulty in semantic processing.

Thus, in the present studies, children were selected if they had a minimum VMA of 4 years. The two clinical groups were also matched as closely as possible on both VMA, and chronological age. This was to ensure the two clinical groups were as similar as possible, with the exception of one group having the diagnosis of autism. In this way it could be argued that any differences found between the two clinical groups was due to the presence of autism and not to overall mental handicap.

2.2: Assessment of Subjects

The assessment used to rate VMA in the present study was the Test of Reception of Grammar (TROG, Bishop, 1983). This assessment tool was chosen because it is arguably a more accurate measure of verbal understanding than a simple vocabulary test. In this test the subjects are rated according to their ability to understand sentences as they relate to a series of pictures. The child does not need to respond verbally; he/she simply has to point to the appropriate picture for the sentence that the experimenter reads out. The test is designed in such a way that at the higher levels the child has to correctly understand the syntax of the sentence in order to choose the correct picture. For example, given the sentence "The girl is pushing the horse", the accompanying pictures are (1) the girl pushing the man; (2) the girl riding the horse; (3) the horse pushing the girl; (4) the girl pushing the horse. When a child fails three consecutive blocks (each block consisting of four sentences and the related pictures) the test is ended. The child is then rated for VMA according to how many blocks he/she successfully passed.

As was mentioned earlier, verbal abilities were chosen as being the most conservative measure of intelligence possible, and also because a minimal degree of verbal comprehension of around 4 years of age was necessary for the majority of the tasks presented in the present study. It was a safe assumption that NVMA would if anything be *higher* than VMA. NVMA was not however tested, to avoid over-testing.

In assessing diagnosis of the subjects included in the experiments, all the subjects with autism were diagnosed by clinical psychologists or psychiatrists using the criteria established by Rutter (1978) and/or criteria specified by DSM-IV (1994) and ICD-10 (1994). Subjects with autism-like symptoms were not included in the study, in order to prevent the possibility of subjects performing differently because they did not have a clear diagnosis of autism.

The subjects with mental handicap[1] included those with general learning difficulties, language deficits, and Down's Syndrome. A check was made of their diagnoses to make sure that none of the mental handicap controls had received diagnoses of autism or autism-related behaviours.

The normally developing controls were included if they were of the appropriate chronological age (4 to 5 years-old) and they had no record of learning difficulties or behavioural problems.

2.3: Subject Details

The subjects with autism all attended special schools for autism in the London area, and all met established criteria for autism (Rutter, 1978; DSM III-R, 1987). Subjects came from a variety of backgrounds and ethnic groups. The male-female ratio was 4:1.

The subjects with mental handicap all attended special schools for mental handicap in Norfolk, and had all been diagnosed as special needs, with problems ranging from general learning difficulties to Down's Syndrome. Again subjects came from a variety of backgrounds, although these children included few individuals from ethnic minority groups. The male-female ratio was 2:1.

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1 N.B.. The term "Mental Handicap" will be used to describe this group of subjects since the term "Learning Difficulties" refers to dyslexia etc., specifically in America, and this control group is more varied.

The normally developing subjects all attended the same primary/infant school in Norfolk. Children came from a variety of backgrounds, although again there were few children from ethnic minority groups. The male-female ratio was approximately 1:1.

Experiments 1 to 3 of the present study tested a slightly different group of children to Experiments 4 to 8. This was mainly due to a year gap between these sets of experiments, which necessitated a new group of normally developing children to be selected with the appropriate age-level required. However, a small number of the original children with autism and children with mental handicap also dropped out after the first 3 experiments, due to moving location, or absence. The two sets of subjects are outlined below.

Table 2:1 - Subject Variables, Experiments 1 to 3.

GROUP		CHRONOLOGICAL AGE	VERBAL MENTAL AGE
Autism (n=17)	Mean	12:9	4:6
	Standard Deviation	2:10	1:5
	Range	7:9-18:0	4:0-10:0
Mental Handicap (n=15)	Mean	12:2	4:6
	Standard Deviation	2:11	0:5
	Range	8:6-18:2	4:0-5:0
Normal (n=17)	Mean	4:10	
	Standard Deviation	0:0	
	Range	4:9-4:11	

Table 2:2 - Subject Variables, Experiments 4 to 8.

GROUP		CHRONOLOGICAL AGE	VERBAL MENTAL AGE
Autism (n=15)	Mean	13:0	4:11
	Standard Deviation	2:2	1:6
	Range	8:9-16:2	4:0-10:0
Mental Handicap (n=14)	Mean	12:8	4:6
	Standard Deviation	2:6	0:5
	Range	9:6-16:8	4:0-5:0
Normal (n=15)	Mean	4:10	
	Standard Deviation	0:09	
	Range	4:10-5:0	

2.4: Some General Methodological Points.

The varying conditions within the experiments in the present study were presented in random order to the subjects, and all subjects eventually received all conditions. With the exceptions of Experiments 6 and 7, where sequencing was a necessary part of the experimental procedure, all experiments were counterbalanced randomly across subjects. This counterbalancing and random allocation of subjects to conditions was to ensure that results obtained from subjects could not become biased due to practice effects, or fatigue effects, since the counterbalancing of presentation should have eliminated any such effects during analysis.

As will also become clear from the descriptions of individual experiments in later chapters, certain relevant experiments were judged by additional independent judges who were blind to the subject diagnoses, and also to the experimental predictions. This procedure was to verify that analyses of subject performances by the experimenter were not biased by any expected results for each subject group.

A final consideration concerns the way in which the experiments reported in the present study were presented. Because of the nature of the subjects involved, that is, all subjects were of a very young mental age, and in the case of the normally developing children a very young chronological age also, the present experiments were all designed to be presented like "games" to the subjects. In this way, it was hoped not only to encourage the subjects to partake in the experiments with enthusiasm, but also to prevent as far as possible any changes in the subjects' behaviour that might have occurred if the subjects believed that they were being "tested" in some way.

All the subjects were seen individually by the experimenter, for each experiment, in a quiet room or corner in their school. Before the experiments were presented to the subjects, a period of casual conversation between experimenter and subject took place, with the experimenter asking questions such as "What have you been doing today?", "Did you have a nice weekend?", "Are you doing anything interesting today?", and so-on, in order to relax the subject and get him/her used responding to the experimenter. Finally, no subject was pushed to respond at any time during the experiments if they did not wish to take part.

This chapter has described basic methodological considerations, and subject details, which apply to each of the experiments reported in the present study. Within each of the later experimental chapters themselves will be full methodologies of the experiments concerned.

To return now to the aims of this thesis, the first aim was to compare performance by children with autism to matched controls on tests of abstract reasoning abilities. Before describing the reasoning experiments conducted in the present study, the next chapter reviews relevant research in the area.

CHAPTER THREE

A Review of Reasoning - Literature and Research

This chapter first reviews theories of normal reasoning and its development, and then examines reasoning research as applies to abnormal development, specifically reasoning in autism and in general mental handicap.

3.1: An Introduction to Theories of Reasoning Development

Human reasoning ability is something that is evidenced everyday, by the child who infers (albeit incorrectly) that 'all birds can fly' after he has experienced just a few examples, to the adult who uses deduction "..to pursue arguments and negotiations...to decide between competing theories, and to solve problems." (Johnson-Laird and Byrne, 1990, pp.35). Johnson-Laird and Byrne argue that an ability to reason underlies the human propensity for science, mathematics, laws, and technology. Without these powers of reasoning, humans would not be the advanced species they are, and would not have developed the complex behaviours and interactions that are fundamental across all human societies.

This ability to perform everyday tasks of reasoning can also be carried over to more abstract tasks of logical reasoning, including propositional reasoning (e.g., *'If P then Q'*, Wason, 1966) and deductive syllogisms (e.g., Aristotle's "categorical syllogisms" - *All*

B *are* A; *All* C *are* B; *therefore all* C *are* A. See e.g., Gilhooly, 1988; Johnson-Laird, 1980) such as are found in formal tests of intelligence.

Psychologists have long been interested in how such a reasoning ability develops. That is, how do children learn to make inferences about things around them, and valid logical deductions?
Is such an ability innate to the human species, or is it something that is learnt and shaped through experience as the child develops?

3.1.i: Piagetian Theory of Intellectual Development.

The work of Jean Piaget has been one of the most influential pieces of research and associated hypotheses relating to childhood development. Although Piaget was interested in far more than the development of reasoning capacity alone, this aspect of intellectual development was a fundamental part of his theory, and the work that Piaget conducted included many experimental tests of reasoning and logic.

Piaget suggested that human intelligence evolves through a series of stages, with previously learned knowledge and experience enabling one to make sense of novel information - a process he termed "assimilation" (where new knowledge is applied to existing knowledge structures) and "accomodation" (where one uses existing knowledge to adapt to the novel demands of new knowledge) (e.g., Piaget, 1950;1970).

Piaget outlined four main stages of intellectual development: sensorimotor, preoperational, concrete operations, and formal operational.

Sensorimotor stage - it was suggested that this primary stage lasted from birth to around two years of age, where infants were mainly concerned with mastering basic skills of sensation and co-ordination (such as tasting things and grasping objects).

Pre-operational stage - this stage was believed to occupy the period from 2 years of age to the child's early school years at around 5 years of age. Here the child starts to master language, symbolic play, imagery, drawing and gesture. That is, he or she is able to start to organise their knowledge about the world and develop some understanding of relations between objects, language, cause and effects, and a basic understanding of concepts. This early stage of intellectual development was believed to be restricted, due to a lack of cognitive flexibility in the child's developing thought processes, leading to phenomena such as the conservation problem - e.g., where the child believes that a quantity of water in a tall thin glass is greater than when that water is emptied into a shorter, wider glass (e.g., Piaget, 1952).

Concrete Operations Stage - with the entry into this stage of development the child is no longer restricted by his or her perceptions, but can now utilise mental and logical processes. In Piaget's terms, the child is now "decentered", and is able to understand classes and hierarchical relationships, as well as pass tests such as conservation. This stage was suggested to cover the mid-school years, between about 6 and 12 years of age.

Formal Operations Stage - in this final stage of intellectual development. the child has a full understanding of reasoning with abstract propositions, and a complete mental logic (e.g., Inhelder and Piaget, 1958). He or she is no longer restricted to reasoning only about concrete, real things, but is able to perform tasks of "hypothetico-deductive reasoning". Piaget argued that it was not until the child reached this final stage of development that he/she would be able to successfully deal with logical reasoning tasks such as deductive syllogisms and propositional reasoning.

Piaget's ideas are not without severe criticism (e.g., Flavell, 1977; Bryant, 1974; Braine and Rumain, 1983) mainly because they underestimate the abilities of the developing child and fail to account for the effects of context. Much research in recent years has demonstrated that children are in fact capable of complex reasoning at a far younger age than proposed by Piaget, as long as the tasks that are presented to the children are relevant to their knowledge. Thus, whereas Piaget suggested that the ability to reason by analogy, for example, did not emerge until the formal operations stage of development in early adolescence (e.g., Piaget, Montangero and Billeter, 1977) other researchers have recently suggested that children as young as 4 years of age are able to demonstrate analogical reasoning capacity (e.g., Gentner, 1977; Nippold, 1987; Alexander, Willson, White, and Fuqua, 1987; Goswami and Brown, 1989; 1990) when the analogical content relates to children's experience (e.g., causal relationships between common objects, such as a knife and an apple - see Goswami and Brown, 1989).

However, Piaget's work provided a rare description of the possible route of intellectual development, along with some critical experimental data, upon which the foundations of much developmental research has been based, including that research which ultimately suggested that Piaget's ideas were too restrictive.

3.1.ii: A Learning Theory Approach to Reasoning Development

This second theory of intellectual development again does not apply purely to reasoning, but has since been related to such development by several researchers. Learning theory posits that an individual will come to develop an understanding of situations through the reinforcement of correct instances, and the non-reinforcement of irrelevant examples. One of the first proponents of Learning Theory was the behaviourist Skinner (e.g., 1948) who was concerned primarily with conditioning responses in animals and relating this to human behaviour. Skinner suggested that one learns what response should be given to a certain stimulus in order to achieve the desired effect or reward, and avoid an unwanted effect or punishment. This extreme and somewhat simplistic view of learning has since been adapted in favour of a more applicable theory of human learning through conditioning, which suggests conditioning involves the formation of cognitive representations of the causal relationships between events (e.g., Dickinson, 1980). Learning Theory as relates to reasoning thus followed the argument that certain rational responses to problems will be reinforced, and irrational responses will not be reinforced.

It is clear that such an argument is somewhat lacking in its ability to explain the development of reasoning abilities in young children. Under what circumstances do children receive the aforementioned reinforcements if they stumble upon the correct, rational response to a logical problem? And unless children are subject to identical problems on a frequent basis, how would they learn to respond rationally to the great variety of reasoning dilemmas present in everyday situations?

Falmagne (1980) suggested that children could develop a schemata that would apply to rules of inference in varied situations, by experiencing patterns of inference about which they receive feedback from reality, or from parents, and from which they then abstract the logical structure that is common to each of these instances. Whilst this argument does appear a more plausible application of Learning Theory ideas than aforementioned examples, unfortunately it does not explain how children come to already posses the cognitive requirements necessary for abstracting the logical relationships they experience. In order to utilise Learning Theory processes in this way, the child needs to already be in possession of a degree of deductive capacity. The circularity of such an argument is obvious.

3.1.iii: Is Reasoning Innate?

The problems experienced by proponents of Learning Theory have been encompassed by this next hypothesis, that of the philosopher Jerry Fodor (e.g.,1980).

Fodor (e.g., Fodor, Fodor, and Garrett, 1975) suggested that the majority of concepts an individual ever holds are innately present, and are only later triggered by relevant learning experiences. He also suggested that the rational, day-to-day functions such as language are controlled by specific modules in the brain, leaving the nonmodular areas free to carry out the thoughtful activities of cognition, including hypothetical reasoning, which are controlled by a central facility. Fodor did not claim, however, to know how this central facility worked, stating that "..practically nothing is known about what happens after the information gets there." (Fodor, 1983, p.127).

In applying his theories to reasoning, Fodor argued that, with the exception of acquiring simple facts, all learning is impossible, and thus is innate. He suggests that this is evidenced by the fact that children have no way of moving from understanding of the propositional logic of inferences, such as:

'If it isn't raining, John is playing outside.
John is not playing outside,
Therefore, it is raining'

to understanding of more complex logical forms, such as:

'If it hasn't rained at some time today, then some children will be playing in every meadow.
No children are playing in some of the meadows.
Therefore, it has rained at some time today.' (Fodor, 1980; see Johnson-Laird, 1987).

Fodor claims that the more complex hypothesis required for the latter problem cannot be encompassed in the conceptual apparatus that exists for understanding of the former problem, because such an apparatus is not rich enough to express such complex concepts. Thus, the cognitive capacity for reasoning has to be innate for each case, since it is not possible for a simple capacity to develop enough to encompass a complex capacity.

This view is clearly too extreme, as it encompasses everything, and proves too much - nothing can develop and everything is innate. Current developmental research with young children demonstrates their adapting to and learning of new concepts, and shows how a partial understanding will sometimes lead to an invalid conclusion (e.g., Farrah, Raney, and Boyer, 1992; Das Gupta and Bryant, 1989). It is apparent that assuming an innate capacity to reason without exploring children's development does not enable understanding of the cognitive processes that are involved in logical reasoning tasks.

3.2: An Outline of Normal Reasoning Development: Inferences, Analogies, Deduction, and Syllogisms.

Having explored some of the basic theories concerning the normal development of intelligence and reasoning capacity, this chapter will now move on to examine individually each of the four main areas of logical reasoning that are studied in reasoning research.

(i) Inferences will be explored first, since recent research has suggested that the capacity for inferential understanding starts to develop around 2 years of age. This will be followed by an examination of the theories and research surrounding: (ii) analogical reasoning, (iii) deductive reasoning, and finally (iv) syllogistic reasoning - each of which shows evidence of emerging competence around 4 to 6 years of age.

3.2.i: Basic Reasoning by Inference

When an individual is said to have made an inference about something, that individual has drawn a reasoned conclusion based on a relationship of information in the individual's knowledge base, which he or she regards as relevant. For example, if presented with the information "John fetched the plane", and knowing that John is in a workshop making a piece of furniture, one would probably infer that the 'plane' referred to is a tool for shaving wood, rather than a Boeing 747!

Transitive Inferences - Piaget (e.g., Piaget and Inhelder, 1956) claimed that young children were unable to form inferences before about 7 years of age, when they have reached the stage labelled as 'concrete operations' and are starting to understand aspects of 'formal operations'. This was supported by studies which asserted that at this age a child could not perform transitive inference tasks relating to quantity or size (e.g., Piaget, Inhelder, and Szeminska, 1966). That is, a child would be unable to infer that A is greater than C, from the information given that A is greater than B, and B is greater then C. Piaget suggested that this failure to pass tests of transitive inference was due to the child's inability to combine the relevant information available in order to make the inference.

However, later studies suggested that Piaget had been underestimating the child's capabilities by not providing enough time for the child to assimilate the information available. Bryant and Trabasso (1971) presented a traditional transitive inference experiment to children between 4 to 6 years of age, where the children were specifically given an extended training period to learn the relationships between the pairs of items presented. Thus, with five stimuli of decreasing size (A>B, B>C, C>D, D>E) the child was shown each pairing separately and asked to say which item was the taller (the stimuli were presented such that it was impossible to tell from perceptual appearance which was taller. The only difference between the stimulus items was colour). Feedback was given as to whether the child's choice was correct, and the training continued until the child could correctly pick the taller item six times in succession.

Once the child had been trained to this level, a series of pairings were presented without feedback, which included both memory pairings (e.g., A>B) and inferential pairings which the child had never seen before (e.g., B>D).

Bryant and Trabasso (1971) found that even children aged 4 years old were able to successfully infer that B was greater than D, when pre-test training had ensured that the relevant information needed to make such an inference had been successfully encoded.

Inferences about Category Membership - More recent research into inferential reasoning in young children has moved away from the more mathematical applications of inference as was explored in transitive inference tasks, and has concentrated instead on the use of inference as applies to conceptual hierarchies. It is believed that individuals form categories on the basis of similarity between objects, and that this information is then organised into hierarchies. Simon (1969) suggested that an important advantage of organising knowledge into conceptual hierarchies and categories is that this then enables inferences to be drawn more easily. However, the process can also be claimed in reverse, that is, by utilising inferential ability an individual is able to identify potential relationships between objects, and thus be aided in the formation of category groups and hierarchical relationships (e.g., Holland, Holyoak, Nisbett, and Thagard, 1986).

The ability to make inferences about category membership has been demonstrated in children as young as 2 years of age. Gelman and Markman (1986) demonstrated that pre-school children were able to ignore obvious perceptual, superficial similarities between objects when making inferences about category membership, in favour of more important underlying properties. They presented children aged 2 to 4 years with pictures of objects (e.g., a flamingo, a bat, and a blackbird). The blackbird and the bat appeared perceptually similar, whereas the flamingo was perceptually dissimilar. However, the children were still able to correctly assert that the blackbird would give its young mashed-up food like the flamingo, and not milk like the bat. Control studies showed that the children were not responding solely according to the category label (e.g., "Bird") since they performed as well under conditions where they were given synonymous labels (e.g., "Rock" and "Stone").

Gelman (1988) went on to explore the kinds of distinctions that these young children are making concerning what properties can and cannot be generalised when making inferences about category membership. She found that pre-school children were less likely to generalise a property that was transient, such as being dirty, than a property that was a lasting condition of an object, such as having a spleen inside.

Davidson and Gelman (1990) demonstrated that this tendency to infer category membership dependent upon non-obvious properties also held true if children were presented with novel objects and labels. 4 and 5 year old children were shown drawings of imaginary animals and taught information about their properties. Each test item was given a novel label (e.g., "this is a biv") and then asked to infer whether another item had the same property (such as having four stomachs). Some of the new items were perceptually very similar to the 'biv', but were labelled differently (e.g., "this is a zav"), whereas some were perceptually quite different, but were also labelled 'biv'.

Davidson and Gelman (1990) found that even when the items presented to the children were novel things that they could not have had experience of before, they still tended to infer related properties on the basis of category membership, and not perceptual similarity.

Deductive Inferences and Hierarchies - However, although young children have been demonstrated as showing valid inferential capabilities when they are working with properties within a given category, that is in *inductive* inferences, studies have shown that children are not as proficient at valid *deductive* inferential reasoning, that is, concerning how categories relate to one another in a hierarchy. For example, knowing general facts about birds, such as they live in nests and they fly, and learning that kingfishers are birds, the child could make the inference that kingfishers live in nests and can fly. Unfortunately, not all birds fly - there are exceptions to the general rule. A penguin, for example, is a bird, but does not fly. In order to successfully make deductive inferences about categories within hierarchies, the child must learn to deal with these exceptions (see e.g., Callanan, 1990).

Smith (1979) demonstrated that by the age of 6 years old, children were able to draw the correct deductive inferences to a series of questions, such as "All chocolate milk has lactose. Does all milk have to have lactose?", or "All milk has lactose. Does all chocolate milk have to have lactose?" (The former question related to an invalid inference, where a novel property was described concerning a subclass, and children were asked if it could be generalised to the whole class, whereas the latter question concerned a valid inference, relating to a novel property attributed to the whole class, and whether it could also be attributed to a subclass.)
The 4 year old children, on the other hand, to whom such questions were presented performed only marginally better than chance. Similar findings have been reported from other researchers (e.g., Harris, 1975; Markman and Callanan, 1984) suggesting that although children are performing well at inductive inference by 4 years of age,

they do not master the more complex deductive inference until they reach around 6 years of age.

The Relevance of Language - Callanan (1990) presented a series of experiments designed to explore how children may come to develop their understanding of categories and hierarchies, thus improving their performance with both inductive and deductive inferential reasoning. She asked mothers and guardians to talk to their children (aged between 2 and 4 years) about various novel objects, some of which related to basic level categories (for example, a koala bear) and some of which related to superordinate categories (for example, vehicles). These novel items were presented along with four related pictures (e.g., four pictures of koala bears, or four different vehicles - a car, a bus, a ship, and a tractor).

Callanan (1990) found that when the mothers were teaching their children about basic level categories they tended to focus on perceptual features (e.g., "He looks soft", or "Look how many toes he has"), and when they were teaching about superordinate level categories, they focused on functional principles (e.g., "People can sit in this and it moves them from place to place"). A related finding was that the mothers concentrated on typical and critical features of the items, and did not draw attention to the more transient, idiosyncratic features.

Studies such as the above, and those relating to the labelling of categories mentioned earlier (e.g., Gelman and Markman, 1986; Davidson and Gelman, 1990) suggest that children may learn how to make valid inferences by utilising a developing understanding of language.

Several other studies have also suggested that language plays a very important role in the young child's developing understanding of categorical relationships and inferences. Markman and Hutchinson (1984) found that when novel names were supplied for category targets, children's ability to then associate items according to taxonomic similarity (e.g., their perceptual appearance and common functions) improved dramatically. Children as young as 2 1/2 years old increased in their taxonomic matching responses from 59% to 83% with basic-level targets, and 4 to 5 year old children also showed a similar improvement for superordinate levels.

Gelman and Coley (1990) discovered that 2 1/2 year old children relied on category labels in particular when inferring identity and properties of novel objects. When children were presented with novel objects which were given category names (e.g., "this is a dinosaur") or adjectives describing transient properties (e.g., "this is awake") they were selective in using only category names to make inferences, and not the transient adjectives. Gelman and Coley (1990) claimed that this was further evidence to support the hypothesis that "..children learn the system of language taught by adults and draw inductive inferences in accordance with that system." (p.802).

Early Bias Towards Taxonomic Categories? - However, other studies have suggested that young children *do not* rely solely on a growing understanding of adult language systems and labelling of categories in order to appreciate categorical relations, and make inferences about those categories.

Fenson, Cameron, and Kennedy (1988) found that children aged between 1 year 11 months, and 2 years 3 months were able to make taxonomic matches between superordinate relations, even when they were trained to match on the basis of perceptual similarity.

Mandler, Fivush, and Reznick (1987) demonstrated that children aged as young as between 1 year 2 months, and 1 year 8 months would engage in touching behaviour between objects from both basic-level and superordinate-level categories, as well as between varied superordinate sets of objects. They claimed that this touching behaviour was demonstrating a tendency on behalf of the child to "comment on" similarities between objects, thus demonstrating an early interest in categorical relationships.

Bauer and Mandler (1989) presented a series of experiments that suggested children as young as 1 year 4 months were capable of producing taxonomic basic-level category matches 72% of the time, with no labels being provided as guidance. Subjects would continue to respond taxonomically even when they were presented with thematic object matches as distractors (e.g., choosing two kinds of toothbrush as a related pair, rather than a toothbrush and some toothpaste), suggesting that children as young as 1 to 2 years of age were competent in classifying objects according to basic-level category classes. Bauer and Mandler (1989) suggested that rather than language being the main force behind young children's early competence in categorical inferences, it merely acts as a reinforcement to aid an ability that is already present in the developing child's understanding of how things in the world relate. They claimed that experiments that found labels and descriptions improved children's inferences would find the same results if those labels were replaced by simple, neutral feedback responses, such as "Uh-huh". In other words, novel labels act as reminders to the subject that they should respond categorically when making inferences, but the subjects are also capable of making basic-level inferences in the absence of labels.

Studies that have explored young children's developing ability to infer relationships between categories, and infer properties according to hierarchical structures and category membership, with or without assistance from language, demonstrate the competencies of children as young as 2 years of age in performing valid inferential reasoning. The conflict surrounding whether linguistic structure guides this ability, or whether there is already present a tendency on behalf of the child to look for certain kinds of relationship in order to store new information in a logical and organised manner, which is later shaped and developed by language as the child's proficiency advances, is a continuing debate. Since studies of children below the age of 2 years have to rely on observation of manual behaviour, or monitoring of attention, they are limited in their capacity to demonstrate existence of inferential abilities as opposed to a simple early understanding of similarities between objects. The aforementioned studies clearly demonstrate the relationship between this understanding of object similarity, and a growing ability to use that information to make inferences about novel objects, but current research can only reliably demonstrate a budding inferential reasoning ability at around 3 years of age.

Having examined the research concerning categorical inferences, this review will now return to its original example of inference, as demonstrated by the understanding of the sentence "John fetched the plane". That is, the way in which inferences are made everyday when people are confronted with language and communication.

Inferences in Language Comprehension - In order to understand many of the sentences, contexts, and conversations in which we are confronted by language on a day-to-day basis, it is necessary to be able to perform a degree of inferential reasoning, or 'filling in of the blanks'. That is, it is a requirement for language comprehension to be able to supply appropriate information that may not be explicitly stated in the text or spoken sentence with which one is faced (e.g., Bransford, 1979). This filling in of the gaps is often achieved according to an understanding of the context in which the language is concerned. Sperber and Wilson (1986) present the following conversational example:

Flag Seller: "Would you like to buy a flag for the Royal National Lifeboat Institution?"

Passerby: "No thanks, I always spend my holidays with my sister in Birmingham."

These two sentences in themselves present no clues as to what the relationship may be between the initial question and the answer given by the passerby. Infact, without the ability to make inferences concerning the meaning behind the passerby's statement, it would be impossible to understand why he replied in the way that he did - the statement on the surface has nothing to do with the Flagseller's question. If, however, one attempts to infer the meaning and context behind such a reply, it is possible to understand the response. In this example, the inference may be something like: Birmingham is nowhere near the sea, so there is no need of the Lifeboat Service. If one doesn't need the skills of the Lifeboat Institution, there is no need to subscribe to that charity by buying a flag from the Flagseller. According to Sperber and Wilson (1986) this is the kind of inferential reasoning that takes place every day as we communicate with one another.

Evidence suggests that most sentences, whether written or spoken, are subject to inferential reasoning at the time of comprehension and storage (e.g., McKoon and Ratcliff, 1981). This often relates to the context in which the sentence is based, and is adapted and updated as necessary depending on further relevant information that may come to light.

Thorndyke (1976) gives the example:

"The hamburger chain owner was afraid his love for french fries would ruin his marriage."

This sentence was followed about a paragraph later by the sentence:

"The hamburger chain owner decided to join weight-watchers in order to save his marriage."

In relating these two sentences, it is possible to infer that the hamburger chain owner was somewhat overweight and decided to shed some pounds so that his wife wouldn't leave him for a slimmer man. Without the latter sentence, one could perhaps have inferred that the hamburger chain owner was so obsessed with french fries he spent his whole day surrounded by the objects of his desire, and his wife was going to leave him because she couldn't compete for his attention, or she couldn't stand the grease and the smell in the bedroom!

Although this is a somewhat jovial example of the importance of inference in language comprehension, it does help to demonstrate how confusing communication attempts would be if one is unable to reason by inference. Thus, the development of inferential reasoning ability from early childhood not only enables an understanding of 'mathematical' problem solving, such as is demonstrated in transitive inference tasks, but also enables an understanding of hierarchical relationships and categories - an important ability if one is to have an organised cognitive store of information that is easy to access and to assimilate, plus the ability to comprehend written and spoken language. Evidence suggests that in the normal brain, this ability to reason by inference shows early signs of utilisation at around 2 years of age, developing into a fuller ability by the time the child reaches approximately 6 years of age.

3.2.ii: Reasoning by Analogy

In order to reason by analogy, one has to reason about the relationship between various pieces of information concerning what it is that connects such pieces of information. That is, to reason about the underlying similarities between sets of information, and how they relate to each other. For example;

Cat is to *Kitten* as *Dog* is to *Puppy*

(Analogies such as the above are often depicted in the form A:B::C:D)

Here, one has to reason about the higher-order relation between the two pairings. In the above example, the higher-order analogical relation would be 'Adult - Young'. Analogies can be concerned with any kind of relation, the point of the analogical reasoning task being that in order to understand or solve the analogy one has to understand the higher-order relation.

Theories about Analogical Reasoning - Some theorists have suggested that analogical thinking arises as the result of brain processes that map the conceptual structure of a base domain (one set of ideas) into another set of ideas (the target domain). This is known as analogical mapping (e.g., Holyoak, 1985; Keane, 1988).

Analogical mapping can be explained as follows: related aspects of the base domain and the target domain are matched, and knowledge about the way those aspects relate to each other is transferred from the base domain to the target domain, thus enabling the individual to relate further items in the same way. For example, in other words, one maps the relationship between the 'A' term and the 'B' term, and thus doing so transfers this knowledge to the 'C' term, enabling the correct analogical match to be chosen for the 'D' term according to the higher-order relationship that now underlies the whole analogy.

Sternberg (1977) presented a componential model of analogy which argued that when an individual reasons by analogy, a number of cognitive processes take place, and that these are processed in serial. First, the terms of the analogy are *encoded*. This enables them to be internally represented during the reasoning procedure. Second, the relationship between the encoded terms of the analogy is *inferred*. Third, the relation between the (A:B) terms and the (C:D) terms is *mapped*, so that when, finally, the C term is *applied* to the choice options the correct analogous choice can be discovered.

Jensen (1980) proposed a theory of reasoning that incorporated an explanation of analogical reasoning. Jensen suggested that that in intelligence there are two distinct levels of thought. Level One is concerned with the initial acknowledgement of new information which is processed and consolidated, but not transferred to deeper cognitive levels. This was thought to relate to such abilities as rote learning, where the information is stored but is not really processed in any detail. Level Two is concerned with the manipulation of stored information in order to arrive at the correct reasoned output. This level relates to higher reasoning abilities such as analogical reasoning. Although Jensen's theory is more applicable to general intelligence development, the argument that in order to reason by analogy one needs to posses the ability to perform higher intellectual functions and detailed manipulation of data suggests that Jensen, like other theorists, postulates an inability by very young children to successfully perform such complex reasoning tasks.

<u>*Analogical Reasoning in Young Children*</u> - Piaget (e.g., Piaget, Montangero, and Billeter, 1977) suggested that children are unable to reason by analogy until they reach the stage of formal operations, in early adolescence. He argued that this was the case because they lacked the ability to reason about the higher-order relations until they reached the level of formal operational logic. Evidence supporting this claim came

from studies where children were presented with sets of pictures, which they had to sort into sets of four that "Go together". For example, Piaget, Montangero, and Billeter (1977) gave children analogies such as "Bicycle is to handlebars as ship is to rudder". The younger children tested tended to select an inappropriate 'D' term, such as another ship, or a duck "because it goes on the water", for example. Piaget et al. argued that this was evidence that young children were unable to take into account higher-order 'analogical' relations, and relied instead on lower-order relations, such as perceptual similarity, or semantic relationships. This claim has been supported by several theorists (e.g., Levinson and Carpenter, 1974; Gallagher and Wright, 1977; Sternberg and Nigro, 1980). Lunzer (1965), for example, presented analogies such as "Black is to white as hard is to soft" to young children, and found that it wasn't until the children reached between 11 and 12 years of age that performance on the task rose above chance.

The idea that young children are failing to pass these traditional analogical reasoning tests due to a tendency to select a perceptually similar object instead of the correct analogically related object, has been supported by a number of researchers.

Holyoak (1985) suggested that young children around the age of 5 years old tend to be drawn to perceptually similar choices, because the surface similarity is the most salient similarity for them to choose as 'novices' in the area of problem solving. Gentner (1988) also argued that young children attempted to solve analogies on the basis of similar appearance, and that they cannot solve such tasks by the correct higher-order relational structure until they acquire a certain degree of knowledge about domain structure, around the age of 7-8 years old.

In a related vein, other theorists have suggested that young children are attracted to choice items which have a high degree of association to the 'C' term of the analogy. This argument stems in part from studies of young children's categorising abilities, similar to those mentioned in the section on inferential reasoning. In these cases, very young children have been demonstrated to pair pictures according to associative and thematic similarities, rather than category relationships (e.g., Nelson, 1977; Markman and Hutchinson, 1984). However, as was explored in the review section on inferential reasoning development, this finding has not been wholly supported (see e.g., Bauer and Mandler, 1989; Fenson, Cameron, and Kennedy, 1988).
Nevertheless, there has been some demonstration of associative matching in analogical reasoning tasks by young children, and since these tasks are arguably cognitively and developmentally more demanding than basic inferential reasoning (e.g., Piaget and Inhelder, 1958) it seems plausible that children may fall back on associative matching when presented with such tasks. For example, Achenbach (1971) found that children under the age of 11 years old tended to choose highly associated items more often than other items - such as selecting the high-association foil item 'cat' when presented with the analogy: *pig* is to *boar* as *dog* is to (*wolf / cat*).

Goldman, Pellegrino, Parseghian, and Sallis (1982) also found that when children under 11 years of age were presented with verbal analogy tasks, such as *hat : head :: shoe : ? (arm, table, foot, lamp)*, they tended to select the commonly associated term (e.g., *foot*). This led to success on many of the analogical tasks, but Goldman et al. (1982) argued that this was not due to a real analogical reasoning ability, but rather it was the by-product of an associative approach, that in many cases happened to also provide the correct solution.

However, more recent studies have suggested that young children perform poorly because of the level of difficulty at which traditional analogical reasoning tasks have been set. It is argued that if tasks were concerned with relations that young children already recognised and understood, then these young children would perform successfully on tests of analogical reasoning.

Goswami and Brown (1989) presented children between the ages of 3 and 6 years old with traditional analogical reasoning tasks of the type A:B::C:D in picture format. However, they based the analogies on a higher-order relation concerned with causality, which is something young children already show evidence of understanding (e.g., Das Gupta and Bryant, 1989). For example, children were presented with pictures representing:

apple : cut apple :: playdough : ? (Cut playdough, cut bread, bruised apple, ball, banana). The higher-order analogical relation concerns the causal mechanism *'cutting'*, whereas the distractor choices related to associative matches, perceptually similar matches, and the correct object with the wrong causal change, or the wrong object with the correct causal change.

Goswami and Brown (1989) found that even 3 and 4 year old children were able to select the analogical choice in this task, where they understood the higher-order relation that was being tested.

In a separate study, Goswami and Brown (1990) strengthened the evidence that young children do not necessarily favour thematically associated choices over analogically correct choices, as long as the task demands are not too high. For example, they presented pictoral analogy tasks to 3 to 6 year old children, since this reduces the pressure on the young child to be verbally competent in order to select an answer. They found that even when young children were given highly associated thematic choices, they were still choosing the analogically correct solution in these less linguistically demanding tasks (e.g., *bird : nest :: dog : ? [kennel, bone, cat, dog]*). Such a demonstration of analogical competence when the child is presented with attractive thematic choices which are commonly known by young children (e.g., dog - cat) emphasises the importance of appropriate task conditions when attempting to gauge the young child's developing reasoning skills.

Nippold (1987) also demonstrated improved performance by young children when presented with analogical reasoning tasks with reduced task demands. Nippold presented 5 year olds with picture matrices depicting analogies, much like the method utilised by Goswami and Brown (1989; 1990) where the child could respond simply by pointing to their choice picture. Without the complexities of verbal task requirements, these 5 year old subjects improved dramatically in their analogical performance.

This demonstration of early competence in analogical reasoning has not been confined to the traditional A:B::C:D analogy tasks alone. Studies which examine the young child's capacity to use problem-solving solutions in stories as analogous solutions to transfer to other problems has also been demonstrated. Brown and Kane (1988) demonstrated that when 4 to 6 year olds are told a story in which a problem is solved using a causal mechanism that they understand, such as using a tool to pull an object into reach, they are able to transfer that solution to a problem which they are presented with in reality (e.g., using a tool to pull a desired toy towards them that they cannot otherwise reach).

Children as young as 3 years of age can even understand the importance of analogy in examples from nature, for example, understanding that some butterflies and moths have large spots like eyes on their wings because this scares away predators, who think it is a face (e.g., Brown, 1989).

It is clear from the studies reported here that children are showing evidence of an early ability to reason by analogy at around 4 years of age. Provided analogical tasks - whether traditional A:B::C:D tasks, or tasks that evaluate the ability to apply analogical solutions to general problems - are set at an age-appropriate level, young children are able to demonstrate a good degree of competence. This is not to say that at 4 years of age a child will be capable of successfully passing all analogical tasks presented. Even adults show some evidence of falling back on the more basic associative-matching techniques when presented with complicated analogical tasks (see e.g., Anderson, 1987; Gentner and Toupin, 1986; Ross, 1984). Nevertheless, evidence suggests that in normal development an ability to reason by analogy has appeared by 4 years of age, far earlier than had been suggested by Piaget for example, when he proposed his theories of intellectual development.

3.2.iii: Deductive Reasoning

Deductive reasoning is a logical process by which individuals work out what conclusion, if there is one, can *necessarily* be drawn from a series of statements, or premises, assuming those statements or premises are true. Studies of deductive reasoning have concentrated, for the most part, on propostional reasoning ability - that is, reasoning about hypothetical states of affairs, often experimentally presented in the logical form *'If P then Q'* (see the earlier section in this chapter, on theories of reasoning development). Theories relating to propositional reasoning abilities basically cover two main camps: (1) Abstract-Rule Theories, and (2) Concrete-Rule Theories. Each of these areas will be explored in turn.

Abstract-Rule Theories of Deductive Reasoning - These theories of propositional reasoning are so-called because they suggest that individuals reason according to abstract rules, or schemata, that can be related to any form of logical reasoning problem. One proponent of such a theory is Braine (e.g., 1978) who argued that people have a natural tendency to reason logically following sets of abstract rules. Human reasoning thus sometimes fails to draw correct logical conclusions because of mistakes made in the initial understanding of the premises or statements around which the reasoning is based, and not because people are unable to reason logically.

Braine (1978) suggested that the abstract schemata with which individuals reason follows the modus-ponens form 'If P then Q'. This relates to any and all situations that require reasoning capacity, for example: If I am hungry, then I will go for a walk

If I go for a walk, I will feel better

I am hungry... (see e.g., Braine and Rumain, 1983; Rumain, Connell, and Braine, 1984; Byrne, 1989).

If an individual then draws invalid conclusions to a problem, they will be one of 3 types. The first type is that of *'comprehension errors'*. This relates to when the initial premises are somehow misconstrued, or misread. The consequent reasoning process will be accurate and logical, but due to the initial misrepresentation of the premises the answer arrived at will be invalid.

The second kind of error relates to *'heuristic inadequacy'*. In this case, the problem is too complex for the reasoning schemata applied to cope with, leading to inadequate strategies being applied, or conflicting during the reasoning process, and consequently leading to invalid conclusions due to a breakdown in the reasoning process. Braine (e.g., 1978) seems to be suggesting that the reasoning schemata may be fine, but the problem is simply too difficult. Presumably, in order to avoid heuristic inadequacy, one would need to develop a more advanced set of abstract rules and schemata.

The final error is concerned with *'processing errors'*. This can be the result of a memory overload, or a simple lapse in attention, or a more fundamental lapse in the application of the appropriate schemata to the problem. This suggests that individuals sometimes draw invalid conclusions because they do not have the resources in memory capacity, or they are subject to attention overload, rather than because they have difficulty in the reasoning process per se.

The basic tenet of Braine's theory, therefore, is that human reasoning is the result of a natural, logical capacity to develop and utilise abstract rules and schemata. This reasoning ability fails in some circumstances because of slips or mistakes in the initial processing of the relevant information, or because of other cognitive influences (e.g., memory span) failing to perform at an adequate level. In other words, if there were no lapses in processing, attention, or memory, for example, adult humans would be naturally capable of logical deductive reasoning at all levels of difficulty.

Experimental evidence to support such a theory includes the suggestion by Geis and Zwicky (1971). They argued that humans are sometimes fallible in their application of logical schemata to deductive reasoning problems, because of a tendency to draw erroneous conclusions during the initial processing of the information. The found that when presented with the statement, "If you mow the lawn, I will give you five dollars" (If P then Q), normal adults would often invalidly reinterpret the information as also meaning "If you don't mow the lawn, I won't give you five dollars" (Not P, therefore not Q) during the comprehension process. Thus, when existing valid, logical reasoning schemata are then applied to the information, the conclusion that is drawn is invalid, not through a fault in the reasoning schemata, but a mistake in the initial comprehension of the information.

A similar error in reasoning is explored by Grice (1975) due to what he called the *'co-operative principle'*. This principle suggests that individuals assume, when processing information, that they will be told exactly the information that they need to know. Once again, this will lead to erroneous, invalid conclusions, even though logical, valid schemata are applied. For example, when told "If it is raining, John will get wet" (If P then Q), and later presented with the information "John is wet" (Q), individuals will reinterpret the initial information as also meaning (If Q then P) "If John is wet, then it is raining". That is, one set of information is thought to contain everything that one needs to know, and can therefore be considered either way round, in this case to draw the erroneous conclusion "Therefore, it is raining". Since the original premise does not logically lead to this conclusion - John could be wet because he fell in the river - Grice (1975) argues that failure to arrive at the logical conclusion is due to an invalid assumption being made in the comprehension of the premises.

Rumain, Connell, and Braine (1984) demonstrated that if individuals are presented with more than one alternative during the initial information given, for example:

> If it is raining, John will get wet (If P then Q)
>
> If it is snowing, John will get wet (If R then Q)
>
> John got wet (Q)
>
> Therefore, ?

they are more likely to arrive at the correct conclusion, that no conclusion can be made, rather than the incorrect conclusion of the kind mentioned earlier. This was taken as further evidence that human reasoning is by nature logical, and follows logical rules and schemata. Any invalid conclusions are drawn not through an invalid reasoning process per se, but through miscomprehension at the initial stage of processing the information presented - a mistake that can be prevented as long as information is designed so as to assist the natural reasoning process (e.g., Braine, 1978).

Although arguments for the existence of abstract-rule theories for deductive reasoning seem to make a certain degree of sense - evidence suggests that with adequate clues individuals will follow a logical course in reaching the valid conclusion - such theories have for the most part only been tested with 'If P then Q' tasks. A theory that revolves around this task in the first place is, by definition, likely to find evidence with these tasks that logical reasoning follows such a design. Also, other more recent studies have found evidence that individuals will actually start to draw *invalid* conclusions when presented with some kinds of additional information, thus presenting a variety of options does not necessarily lead to an improved ability to apply logical schemata. For example, Byrne (1989) presented subjects with the following:

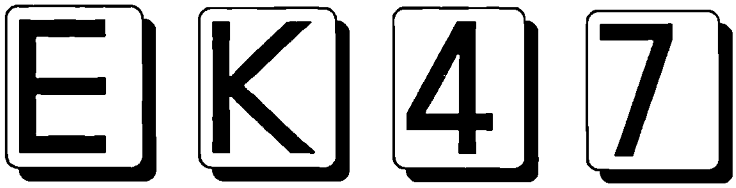
> If she has an essay to write then she will stay late in the library (If P then Q)
>
> If the library stays open then she will stay late (If R then Q)
>
> She has an essay to write (P)
>
> Therefore, ?

He found that the additional information actually hindered subjects in making the valid modus-ponens deduction (Q) "She will stay late in the library".

Thus, abstract-rule theories of deductive reasoning can appear reasonable when applied in certain situations, but evidence suggests that individuals perhaps do not automatically reason according to abstract, logical schemata. This leads on to the next main theory about deductive reasoning, that concerned with concrete-rules.

Concrete-Rule Theories of Deductive Reasoning - This kind of theory posits that individuals perform differently if presented with concrete materials with which to work, rather than abstract statements, and that to reason following a set of concrete rules is infact the natural way in which humans deal with deductive logic. These rules are domain-specific, applying only to the circumstance which is presented, rather than domain-general and applicable to every potential circumstance, as is argued by abstract-rule theory.

The main task that has been used to test understanding of the 'If P then Q' proposition in a concrete form is the *Wason Selection Task* (Wason, 1966). The task involves subjects being presented with a set of 4 cards, laid out infront of them. In the abstract form of the task, the cards have vowels, consonants, odd and even numbers on them (one on each side of the cards). Subjects are told the rule "If there is a vowel on one side of the card (P), then there is an even number on the other side of the card (Then Q)." Subjects then have to indicate which cards need to be turned over to test the validity of the rule. Thus, if presented with cards showing the following:



where the rule could be redefined, left to right, P, Not-P, Q, Not-Q, the subject should turn over the E card (P) and the 7 card (Not Q) to logically test the original rule presented.

However, in an abstract form like the one above the Wason Selection Task tends to be only performed correctly by about 4% of adult subjects (e.g., Johnson-Laird and Wason, 1970). When the task is varied to involve concrete materials, subjects show a greatly improved performance. For example, Johnson-Laird, Legrenzi, and Sonino-Legrenzi (1972) gave subjects who worked in a post-office the rule: "If a letter is sealed, then it has a 5d stamp on it." The subjects were then shown 4 envelopes - back-view clearly sealed, back-view clearly unsealed, front with a 5d stamp, and front with a 4d stamp. They found that over 90% of the subjects made the logically correct selections in this concrete version of the task (i.e., chose to turn over the clearly sealed letter, and the letter with the 4d stamp on it.)

This finding has been replicated by other researchers (e.g., Griggs and Cox, 1982,1983; Reich and Ruth, 1982). Griggs and Cox, for example, found that performance on the Wason Selection Task was facilitated when students in Florida were presented with the rule: "If a person is drinking beer, then that person must be over 19 years of age", and shown 4 cards, visibly depicting a bottle of beer, a bottle of coke, an adult over 19, and a juvenile under 19. The students had little difficulty in selecting the 'beer' card and the 'juvenile' card as the two that needed to be turned over to test the rule (Griggs and Cox, 1982).

However, Manktelow and Evans (1979), among others, found that when they presented other concrete materials to adult subjects (for example, "If I eat haddock, then I drink gin"), the subjects did not demonstrate the improvement in performance that was expected according to the concrete-rule theory. This finding raised questions about the nature of the facilitation effect that had been observed - was it due simply to using concrete, realistic materials, or was it due to what theorists dubbed a *'memory-cueing hypothesis'* (e.g., Griggs, 1983; Reich and Ruth, 1982)?

The memory-cueing hypothesis suggested that subjects would only be facilitated in their performance if the concrete items which were used related to the subjects specific experience. Thus, the post-office workers performed well in the study by Johnson-Laird, Legrenzi, and Sonino-Legrenzi (1972) because the concrete items related to things with which the post-office workers had day-to-day experience - i.e., envelopes bearing 5d stamps. Similarly, the Florida students performed well in Griggs and Cox's (1982) study because they had direct experience of the drinking-age laws in Florida.

This hypothesis seems more applicable than a general concrete-rule theory of deductive reasoning in explaining facilitated performance on the Wason Selection

Task, but it perhaps narrows the theory too far, since it implies by definition that individuals would not be able to facilitate their performance under any circumstances where they have not had direct experience. Thus, following this hypothesis, anyone who has not worked in a post-office in 1972 should not be able to easily pass the Johnson-Laird et al. (1972) task. Common-sense tells us this is not the case.

D'Andrade (1980) demonstrated empirically that direct experience is not a necessary requisite to facilitation with concrete items in the Wason task. He asked subjects to imagine they were managers of a large department store, and were responsible for checking sales receipts. He gave them the rule "If a purchase exceeds $30, then the receipt must be approved by the department manager." They were shown 4 'receipts': $15, $45, signed, and not signed. Even though the subjects had no direct experience of managing a large department store, they were able to make the correct deductions as to which receipts had to be checked to verify the rule over 70% of the time.

In order to explain such findings, the concrete-rule theory was adapted to suggest that individuals could apply analogous past experience to the problems, thus facilitating the deductive task. In other words, different degrees of past experience would assist the problem-solving strategy in varying ways, with subjects making an *association* between the concrete items presented and any applicable past experience they had had, in order to utilise that past experience in the present concrete task. This kind of hypothesis on deductive reasoning has been called *"Availability Theory"*, in that the more experience a subject has had with associated events or items in the 'P' and 'Q' parts of the Wason Task, the more readily *available* they will be as part of the cognitive response.

Pollard (1982) claimed that subjects would make their choice selections in the Wason Task dependent upon the past associations that come to mind most readily. If, for example, a subject has had experience of eating haddock whilst drinking gin, he may well have shown facilitated performance in the task by Manktelow and Evans (1979) mentioned earlier. On the other hand, if a subject has had no such experience, and can think of no analogous experience, but rather may have had common experience of eating haddock whilst drinking coffee, the responses he makes may be related to his own personal experience bias.

An alternative explanation to the results shown with concrete examples of the Wason Selection task has been posited by Cheng and Holyoak (1985). They suggested that the rules which individuals apply to the task are sensitive to particular classes of situations, and relate to the pragmatics of the situations. They call such rules *"Pragmatic Reasoning Schemata"* (Cheng and Holyoak, 1985). The pragmatic reasoning schema theory proposes that there are two main kinds of context-specific rules which individuals apply to Wason-style deductive reasoning tasks: (1) *Permission schemata* - which take the form "If one is to do X, then one must satisfy the precondition Y"; and (2) *Obligation schemata* - which take the form "If situation A arises, then situation C must be done".

Thus, there are two main reasons for errors in deduction in the Wason task. Firstly, if the concrete situations presented cannot be easily mapped into pragmatic schemata, errors will be more likely to occur. Secondly, individuals will sometimes make erroneous selections *because* of the schemata that have been applied to the task, since logical rules and pragmatic schemata do not always conform.

In one experiment (Cheng and Holyoak, 1985) they presented subjects with a 'permission' problem that stated: "Suppose you are an authority checking whether or not people are obeying certain regulations. The regulations all have the general form, 'If one is to take action A, then one must first satisfy precondition P'." (See Cosmides, 1989, pp.205).

An alternative, non-permission problem was "If a card has A on one side, then it must have a 4 on the other side."

Cheng and Holyoak (1985) found that 61% of the subjects chose the correct 'P' and 'not-Q' responses with the permission problem, whereas only 19% of subjects chose 'P' and 'not-Q' with the non-permission problem. Not only does this finding lend support to the Pragmatic Reasoning Schemata hypothesis with the evidence that subjects perform more accurately when given specific permission rules, but it also suggests that such an improvement in performance can even be obtained with 'abstract' items (letters and numbers), as long as the rules follow individual's natural understanding.

However, recent work conducted by Cosmides (1989; Cosmides and Tooby, 1989, 1994) has suggested that neither Pragmatic Reasoning Schemata nor Availability Theories are fully able to explain individuals reasoning processes. As an alternative, Cosmides proposes an hypothesis of deductive reasoning called *"Social Contract Theory"*. Social Contract Theory posits that people reason according to social rules that they apply to the problems. These social rules have developed because of an evolutionary need to understand social behaviour and to manage social interactions, thus leading to a tendency to store learned information according to a computational theory of social exchange. In other words, humans adapted to understand each other and cooperate for mutual benefit, thus building up mental algorithms based on social contracts, which regulate reasoning processes in social situations (Cosmides, 1989, pp.193).

Social Contract Theory is different from Availability Theory because it concentrates not on general past experiences, but upon a set of specifically social rules concerning interaction and cooperation, which humans have evolved to apply to any social situation. It is different from Pragmatic Reasoning Schemata because it does not limit itself to permission and obligation rules - which need not always be social - but encompasses any kind of problem that has an element of social content.

In a series of experiments Cosmides (1989) tested Social Contract theory against both Availability Theory, and Permission Schemata:

Social Contract versus Availability Theory - The first experiments compared subjects performance on a variety of Wason-type tasks that involved either unfamiliar 'standard' social contract problems (e.g., "If a man eats cassava root, then he has a tattoo on his face"), and unfamiliar 'switched' social contract problems (e.g., "If a man has a tattoo on his face, then he eats cassava root") - with each social contract problem the rule to be tested was preceded by a detailed narrative which described the social laws, or private social exchanges, which led to the formation of the rule (such as gaining a tattoo when one gets married, and cassava root being a powerful aphrodisiac drug that is only allowed to be eaten when in the sexually moral confines of marriage) - or an unfamiliar descriptive problem (the same rule was presented, but the preceding narrative laid out a detailed description of tribal members being observed eating cassava root and having tattoos on their faces, which did not discuss any social elements at all), or a familiar descriptive problem (e.g., "If a person goes into Boston, then he takes the subway", together with a detailed purely descriptive explanation), or finally, an abstract problem (e.g., "If a person has a 'D' rating, then he must be marked code '3'", with a set of non-social instructions explaining the rule).

Cosmides (1989) claimed that Availability Theory would predict few logical 'P, not-Q' responses for all unfamiliar rules, regardless of whether they were descriptive, abstract, or social, and would never predict a 'Not-P,Q' response under any circumstance. Social Contract Theory, on the other hand, predicts many 'P, not-Q' responses to standard social contract problems, and many 'Not-P, Q' responses to 'switched' social contract problems, regardless of the degree of familiarity or unfamiliarity. Results supported these claims, leading Cosmides to suggest (1989, pp.228) that social contract algorithms are the main determinant of responses to Wason Task problems that have a social element. This is independent of the need for past experience or familiarity, and was not 'associated' to descriptive problems as would have been the case if availability theory was in action.

Social Contract versus Permission Schema - Cosmides argued that the main difference between Permission Schemata and Social Contract is that the former is processed according to "actions to be taken" and "preconditions to be satisfied" (e.g., "If you are going to do X, you have to satisfy precondition Y"), whereas the latter is processed according to "perceived benefits" and "perceived costs", relating to social exchanges between individuals and/or groups. She argued that "All social contract rules involved permission...or entitlement, but not all permission rules are social contract rules." (1989, pp.236).

When Cosmides tested non-social permission rules, both standard and 'switched', against standard and 'switched' social contract rules, she found that a high percentage (65-80%) of logical 'P, not-Q' responses was elicited for all social contract rules, but only a maximum of 45% of such responses was demonstrated for permission-rules, with 'switched' permission-rules eliciting as little as 0-10% 'P, not-Q' responses. This supported the hypothesis that humans naturally reason according to social rules and not the more general rules implied by Cheng and Holyoak's (1985) Pragmatic Reasoning Schemata.

In drawing her conclusions, Cosmides posited the hypothesis that humans have specialised algorithms, with certain structural properties, to reason about social exchanges, and that these algorithms are innate.

The theories relating to deductive reasoning discussed here have all shown some evidence of being applicable to the way in which humans reason when confronted with deductive reasoning tasks of the propositional 'If P then Q' kind, whether in abstract or concrete format. Evidence from the more recent theories, such as Cheng and Holyoak's (1985) Pragmatic Reasoning Schemata, and Cosmides (1989) Social Contract Theory, seem to be more able to explain performance in both abstract and concrete tasks, by suggesting that humans apply certain kinds of socially learned rules to reasoning. Cosmides' hypothesis is more specific in this respect than that of Cheng and Holyoak, since it limits reasoning rules to social situations alone. However, because Cosmides' hypothesis concentrates upon social problems, it perhaps fails to explain how individuals ever learn to solve non-social deductive problems in a logical fashion, which clearly does occur. Perhaps she would argue here that there is an element of Availability Theory, and that social contract rules are associated with non-social situations in an attempt to apply the same rules to those conditions also? However, if this were the case, then surely Cosmides would have demonstrated good performance in some of the non-social tests that she presented. As it stands, Social Contract Theory has a strong developmental and evolutionary basis, and it explains many of the errors that are made in deductive reasoning, but it cannot fully explain the logical reasoning capabilities of normally developing adults.

A further point to note following this section of the review is that the studies reported here concentrate upon adult reasoning. There is a paucity of experimental work in the area of logical deduction and children with tasks such as those reported here, so at present it is difficult to suggest an age at which propositional deductive capabilities start to emerge. However, propositional reasoning (If P then Q) is often closely associated with syllogistic reasoning (e.g., All A are B, All C are B, therefore all C are A) since this also involves logical conclusions being drawn purely from the information present in the premises, and much more work has been conducted into the syllogistic reasoning abilities of young children.

3.2.iv: Syllogistic Reasoning

As has been mentioned, there is a close association between propositional reasoning tasks and syllogistic reasoning tasks - both kinds of problem involve deductive reasoning. In order to explore the literature covering deductive reasoning studies and hypotheses in a more organised fashion, syllogisms and propositions have been separated in this review. However, since both are forms of deduction there is a great deal of overlap between the related research studies and hypotheses, and this overlap will be to an extent unavoidable in this review, for fear of misrepresenting the intricate connections between the various branches of logical reasoning research. For this reason, reference will be made to studies which could apply equally to syllogisms or to propositions. Endeavours will be made to draw attention to this interconnectedness when such instances occur.

Although a syllogism is technically defined as any argument that consists of two premises followed by a conclusion, the majority of studies examining syllogistic reasoning have utilised the well known style of Aristotle's *'categorical syllogisms'*. Categorical syllogisms follow the general pattern: All B are A (premise 1)

All C are B (premise 2)

Therefore, all C are A (conclusion)

However, syllogisms are not limited to using "All" in the premises (the universal quantifier), they can also use "Some" (the particular quantifier), and negatives (e.g., none). Thus, for example, one could have a syllogism that reads:

Some of the artists are beekeepers (premise 1)

All of the beekeepers are chemists (premise 2)

Therefore, ? (conclusion [Some of the artists are chemists]). (See Johnson-Laird,1980)

The Atmosphere Hypothesis of Syllogistic Reasoning - This was one of the earliest attempts at an explanation of syllogistic reasoning performance, proposed by Woodworth and Sells (1935). Basically, what Woodworth and Sells suggested was that individuals would be confused, or biased, by the overall 'atmosphere' of the premises, leading to invalid conclusions. For example, if the syllogism starts with premise 1 being negative people will read it as a negative syllogism, regardless of whether the second premise is affirmative, and will consequently tend to draw a negative conclusion. The same is the case if the first premise is particular, and the second is universal, and so-on. Closer examination of the atmosphere effect has suggested that it is more often found when the syllogism has a valid conclusion (e.g., Begg and Denny, 1969; Johnson-Laird, 1980).

However, Johnson-Laird and Steedman (1978) demonstrated that sometimes people would conclude that a syllogism leads to no valid conclusion at all, even though there is, in fact, a valid conclusion that can be drawn. For example, in the "beekeepers and artists" syllogism above the majority of subjects would claim there is no valid conclusion. Johnson-Laird and Steedman (1978) claim that this phenomenon raises serious doubts about the atmosphere hypothesis, since the atmosphere hypothesis would not only predict a valid conclusion in these situations, but the valid solution should be correct if following the *particular atmosphere* created by the first premise.

The Conversion Hypothesis of Syllogistic Reasoning - An alternative explanation was posited by Chapman and Chapman (1959). They claimed that individuals will often draw invalid conclusions because they have misinterpreted the premises during processing. This misinterpretation takes the form of *converting* the premises. Thus, when presented with the premise "All A are B", people will assume that because it is a universal the converse is true - i.e., "All B are A". (Similarities can be seen here with Grice's (1975) Co-operative Principle of propositional reasoning, mentioned earlier in the chapter.)

Ceraso and Provitera (1971) supported the conversion hypothesis in an experiment that demonstrated how individual performances on syllogisms could be improved if the premises were less ambiguous. For example, they gave subjects initial premises that read "All A's are B's, but some B's are not A's" , instead of simply "All A's are B's". By clearly stating the logical relationship in this way, Ceraso and Provitera (1971) enabled subjects to understand the syllogism more easily, thus improving overall performance.

Representing Syllogisms by Euler Circles - Other explanations for the way in which humans perform syllogistic reasoning tasks includes the claim by Erickson (1974) that the premises of the syllogisms are represented by the individual in the form of Euler circles - mathematical circles that overlap according to interconnections between sets of information. He suggested that only one representation is formed for each premise, and thus the premise "All A are B" for example, will sometimes be represented as one circle A within a larger circle B, and sometimes represented by two overlapping circles. Unfortunately, Erickson (1974, 1978) does not explain the full mental process involved in constructing these circles, such as how one goes about combining all the representations from the relevant premises to create a conclusion representation. Other theorists (e.g., Johnson-Laird, 1980) have pointed out that since the Euler circles are symmetrical, they would end up corresponding to more than one possible conclusion - e.g., they would equally represent "Some A are C" and "Some C are A" (see Johnson-Laird, 1980, for a review.)

The Mental Model Theory of Syllogistic Reasoning - Probably the most widely considered current hypothesis of the cognitive processes behind syllogistic reasoning comes from Johnson-Laird himself (1980;1983;1987). He proposed a "Mental Model Theory" to explain the way in which individuals deal with the premises of a syllogism, and also with other forms of deductive reasoning, including propositions. According to this theory, it is possible to work out the valid conclusions to syllogisms by forming alternative models of the scenario reported in the premises, via a purely cognitive process - that is, to form several alternative *mental models* which do not violate the meaning of the premises, to see which conclusion should be validly drawn. Johnson-Laird does not specify whether the mental models are pictoral (i.e., specific mental images of the characters in the premises, such as a visual mental representation of lots of singers) or in some other format, since it is the process by which the models are created and utilised in reasoning that interested Johnson-Laird, rather than the nature of the models themselves. For simplicity, however, his examples take a particular form. An example supplied by Johnson-Laird (1980) is as follows:

Given the premises "All of the singers are professors,

All of the poets are professors,"

one can form a variety of mental models. These models can all be true to the premises, whilst all being different representations.

For example:

singer = professor = poet

singer = professor = poet

singer = professor = poet

(professor)

(professor)

(professor)

where the parentheses are individuals that, according to the original premises, may or may not exist.

An alternative could be:

singer = professor = poet

singer = professor = poet

singer = professor

professor = poet

(professor)

(professor)

whilst another option would be:

singer = professor

singer = professor

singer = professor

professor = poet

professor = poet

professor = poet

All of the above models are true to the premises, but if one was to build only the first model shown, or only the second model shown, it would lead to an invalid conclusion (Johnson-Laird, 1980). In order to draw the valid conclusion, that there is *no* conclusion that can be drawn from the premises given, one needs to have constructed a *range* of mental models, all of which represent the premises, until all options have been exhausted, and then to "test [the selected] model to destruction."(1980, pp.81).

More recently, the problem of negative syllogisms has been explored (Johnson-Laird and Byrne, 1990) with the suggestion being that exactly the same procedure is used, the difference being the addition of 'tags' to the individual elements of the model to represent negation. (Thus, the premise "None of the singers are professors" could be represented as - singer = ¬professor, or ¬singer = professor.)

Johnson-Laird (1980;1983; Johnson-Laird and Bara, 1984) argued that individuals thus give invalid conclusions because they have not exhausted the possible range of models representing the premises. Since some syllogisms are more complex than others - i.e., some can be solved with only the representation of one or two models, whilst others require several different models before a valid conclusion can safely be drawn - problems occur with the more complex syllogisms due to limited working memory capacity. Johnson-Laird and Bara (1984) demonstrated this experimentally when they gave different syllogisms of varying complexity to subjects. The syllogisms that required a high number of alternative models to be constructed were given valid conclusions less often than those which required a small number of models to be considered. This finding was replicated (Johnson-Laird, Byrne, and Schaeken, 1989; Johnson-Laird and Byrne, 1990), along with evidence that the conclusions being drawn were consistent with the subject constructing initial models, but neglecting to construct all possible alternatives (see the example represented earlier).

Other evidence to support the mental model theory includes the demonstration that the theory still holds true for multiply-quantified assertions (e.g., "None of the beekeepers is taller than any of the chemists", Johnson-Laird, Byrne, and Tabossi, 1989) whilst other model theories such as Erickson's Euler Circles fail to predict performance or explain the layout of such models.

Also, Johnson-Laird and Byrne (1989) predicted that if a subject was given a syllogism which included the term 'only' instead of 'all' it would prove much harder to draw a valid conclusion, even though logically 'only' and 'all' should be equivalent. This was proved to be the case (Johnson-Laird and Byrne, 1989). It was argued that the recorded deficit in performance with such syllogisms was because when one represents 'only' the representation is more complex than the representation of 'all', and it tends to emphasise negatives. For example, given the premise "Only criminals are psychopaths", an individual will immediately consider that some criminals are psychopaths, and anyone who is not a criminal is therefore not a psychopath. Given instead "All psychopaths are criminals", which is logically identical in meaning, individuals will consider that there may be criminals who are not psychopaths, but Johnson-Laird and Byrne argue this is less obvious than in the 'only' syllogism. Thus, positive syllogisms which include 'only' are harder than those which include 'all' as a quantifier, whereas conversely because a representation of 'only' arguably highlights negative relationships, negative syllogisms which include the quantifier 'only' become *easier* than those including 'all' (Johnson-Laird and Byrne, 1989).

Johnson-Laird (1980) claims that not only does the mental model theory apply accurately and effectively to any form of syllogism, but it also can explain children's developing ability to reason by logical inference. Since the theory contains no rules of logical inference in its application, merely a procedure for testing any models formed - which need not utilise inferential logic at all - it is argued to explain development of reasoning through a learning process where the reasoning comes first, and any formal logical rules are learnt as an aside (see Johnson-Laird, 1980, pp.83-84).

Generally speaking, the mental model theory has held up to any criticisms successfully and is still regarded as one of the major theoretical explanations as to how syllogistic and other deductive reasoning tasks are performed. However, an alternative explanation as to how reasoning is performed has been proposed by Rips (1989; 1990) who claims that rather than reasoning with a format that requires no rules of inference, as Johnson-Laird has proposed, people actually *rely* on rules of inference to successfully deal with logical reasoning tasks. Rips (1989; 1990) posits a natural-deduction theory, similar in its original basis to that of Braine (1978) reported earlier. The evidence he presents for his arguments comes from a series of experiments which explored individuals performances on *'paralogical'* reasoning tasks - namely, sentential problems known as knight/knave puzzles, where knights only tell the truth, and knaves only tell lies. An example of a knight/knave puzzle would be:

George says, "Both Martha and I are knights", but when we consult Martha, she says "George is a knave." Is George a knight or a knave? What about Martha?

(See Smullyan, 1978; Rips, 1990).

Rips (1990) argues that the Mental Model theory cannot explain how people solve such problems, since constructing a mental model of the information presented will tell you nothing about the relationships between the relevant sets of information. Knight/knave problems explore reasoning performance when the conclusion is not explicitly provided in the puzzle, as is the case in syllogisms and propositions, and thus mental models are of no use - according to Rips - because they only work if all the necessary information in explicit in the task. Rather, Rips (1989) argues that people apply a series of assumptions to the problem, and attempt to solve the problem following a set of inference rules. For the George-Martha problem, the natural-deduction explanation would be as follows (see Rips, 1990):

(1) The system assumes George (the first character encountered) is a knight.

(2) Inferential rules of reasoning are applied to this assumption, with 3 possible outcomes to the puzzle - (i) the model could deduce that Martha is both a knight *and* a

knave, which would lead to a halt of the program and a subsequent reversal of the original assumption; (ii) the model could determine the status of all characters following the original assumption, save this information for the record, and try the same process with the opposite assumption, in case there is an alternative possibility; (iii) the deductions could lead to at least one of the characters having an undetermined status - either a knight *or* a knave. The model would then make a *new* assumption about this undetermined character, and proceed as from the initial assumption, until a satisfactory status has been assigned.
Rips (1990) claims that evidence to support this comes from studies that have shown that performance is slower and prone to more errors if the puzzle presented has more stages through which one needs to progress. In addition, he claims that subjects show no deficit in performance speed or a higher rate of errors in tasks that require a greater number of mental models to be formed - contrary to the claims by Johnson-Laird and Byrne (1990) - showing that mental model theory is less able to account for subject performance in paralogical reasoning tasks.

Johnson-Laird and Byrne (1990) proposed additional reasoning strategies to sit alongside the mental model theory which would explain subject performance in the light of Rips' (1990) claims. These strategies guide the mental model process in a sequential order, since the mental model process alone does not necessarily follow a set order of reasoning, and where necessary halt the process if the task is too complex, for example. However, Rips (1990) argued that the strategies reported "are ad hoc, rather than being derived from some more general theory" (1990, pp.313), and that by turning to strategies to explain individuals performance where the mental model theory fails, Johnson-Laird and Byrne have only succeeded in emphasising the inadequacy of the mental model explanation.

It is clear that the battle between mental models and inferential rules is unresolved at this moment. Both hypotheses can offer explanations for reasoning performance, with the mental model evidence being more directly applicable to traditional syllogisms, perhaps, than the natural-deduction theory posited by Rips (1989). However, regardless of whether individuals reason about syllogisms using inferential-logic-free mental models, or following a specific set of deductive inferential rules, the subjects that have been studied in the reports mentioned thus far have always been normal adults. To address some balance to the exploration of the development of logical reasoning, this review will continue next with an exploration of syllogistic reasoning performance in young children.

Syllogistic Reasoning - Studies with children - Until relatively recently children have not been used as subjects for logical reasoning tasks involving syllogisms, possibly because of the claim by Piaget (e.g., Inhelder and Piaget, 1958) that children cannot comprehend formal logic of this kind until around their early teens. However, much research in recent years has questioned this assumption, with evidence that under certain conditions children as young as four years old demonstrate syllogistic reasoning capacity.

Hawkins, Pea, Glick, and Scribner (1984) presented 4 and 5 year old children with a series of verbal syllogisms, some of which concerned fantasy situations and characters, some which were about real-life characters, but incongruent to children's experience, and some which were both about reality characters and containing congruent information. Examples of these three conditions are shown below (see Hawkins et al., 1984, pp.587):

Fantasy - Every banga is purple.
Purple animals always sneeze at people.
Do Bangas sneeze at people?

Incongruent - Rabbits never bite.
Cuddly is a rabbit.
Does Cuddly bite?

Congruent - Bears have big teeth.
Animals with big teeth can't read books.
Can bears read books?

Hawkins et al. (1984) found that children were able to perform well above chance on the syllogisms that involved fantasy content, or content that was congruent to their real-world knowledge. However, the children performed below chance on the syllogisms that involved incongruent information which went against their real-life experience. Nevertheless, the findings demonstrated that under certain circumstances, children as young as 4 years old can reason in a deductive manner.

Hawkins et al. (1984) also examined the justifications that children gave as to why they chose the answer they did. These justifications were coded as (i) theoretical - if they related to the content of the syllogisms (e.g., "Yes, Bangas sneeze, because purple animals sneeze at people."); (ii) empirical - if they related to the child's real-world knowledge (e.g., "Yes, Cuddly bites, because my rabbit bites."); (iii) state - if the child simply repeated the identity of the creature (e.g., "Yes, because he's a Banga."); or (iv) no response given. The finding was that children would most often give theoretical (deductive) responses when they answered the syllogism correctly, supporting the argument that these young children were really demonstrating logical reasoning ability.

In addition, syllogisms were easier for the children to solve when they were directly related pragmatically (e.g., "Godes have skinny legs. Animals with skinny legs can't dance. Can Godes dance?" (1984, pp.590)). Syllogisms where the second premise was pragmatically unrelated proved more difficult.

A final finding by Hawkins et al. (1984) was that there was an order effect on performance. Children would give significantly more theoretical justifications when they received the fantasy problems first, and would give significantly more correct responses overall. It was argued that this demonstrated the children's ability to use unfamiliar information in a logical manner, as long as real-world knowledge was irrelevant (fantasy conditions) or they had had some 'practice' through first answering the fantasy problems, as this demonstrated that real-world knowledge may not always be relevant.

In two similar studies, Dias and Harris (1988; 1990) presented 4, 5 and 6 year olds with syllogistic problems that included counterfactual information - that is, like Hawkins et al.'s (1984) incongruent information - contrary to real-world knowledge. In the first set of experiments (1988) counterfactual, factual, and unknown fact syllogisms were presented in a play situation, using relevant props and toys to 'enact' the syllogistic premises, and then counterfactual syllogisms alone were presented either (i) with the toys used to enact the premises still being visible when the conclusion question was asked, or (ii) with the toys hidden for the conclusion question, then (iii) with the toys 'enacting' life on another planet in a box that either the child could see into, or the experimenter alone could see into and describe to the child, and finally (iv) where the children were simply told that the syllogism was about another planet, or was told the syllogism in a matter-of-fact voice with no mention that they were pretending it was another planet. The latter parts of the study only explored counterfactuals because these were the syllogisms that demonstrated the greatest difference in performance between verbal and play conditions. Thus, Dias and Harris also manipulated contexts in their study. Examples of the syllogisms (see Dias and Harris, 1988, pp.221) are as follows:

Known facts -	All cats miaow.
	Rex is a cat.
	Does Rex miaow?

Unknown facts -	All molluscs live in a shell.
	Tot is a mollusc.
	Does Tot live in a tree?
Contrary facts -	All cats bark.
	Rex is a cat.
	Does Rex bark?

As with Hawkins et al. (1984), the children were asked to give justifications to their responses. These were recorded much like the Hawkins et al. study, with empirical, theoretical and arbitrary (no response, irrelevant, indecipherable, etc.) justifications. Dias and Harris (1988) found that children performed well when the syllogism was play-acted using toys and props, but not very well in a verbal only presentation. The latter part of the study demonstrated that this improvement in performance for pretend/play situations continued when it was present in any context, whether using toys that were visible, toys that only the experimenter could see, or simply telling the child to pretend that the premises were about another planet. In addition, children in the play conditions offered more theoretical justifications than children in the verbal conditions. Dias and Harris (1988) argued that the findings demonstrated that young children could reason logically with counter-to-fact information as long as the context in which the information was presented ensured that their real-world knowledge did not intrude upon the reasoning process. Thus, it is not only the content of the syllogisms that is relevant, as Hawkins et al. (1984) argued, but rather the context, since this will enable an improvement in performance regardless of the content.

To further strengthen this argument, Dias and Harris (1990) conducted another study exploring 4 year old children's reasoning with counterfactuals. They presented the children with counterfactual syllogisms in one of 8 different conditions, made up of a combination of binary variables - story intonation, or matter-of-fact intonation; reference to a make-believe planet, or no reference to a make-believe planet; instruction to use imagery (picture the premises in their head), or no imagery instruction (1990, pp.305). As before, the subjects were asked to justify their responses, and justifications were recorded either empirical, theoretical, or arbitrary.

Dias and Harris found that the introduction of just one of the variables - a make-believe planet, a story intonation, or imagery instruction - was enough to enable the children to reason deductively and perform well above chance on the syllogisms (mean number of correct responses was at least 3 out of 4). The only condition where the children performed poorly was the matter-of-fact intonation, no imagery, and no-planet condition, with a mean of 0.75 correct responses. Once again, a greater number of theoretical justifications was produced for the 7 conditions where the children performed well, whilst in the poor performance condition greater numbers of empirical and arbitrary justifications were offered. This study demonstrated that the introduction of any variable that assists the child in ignoring real-world knowledge will lead to significant demonstrations of logical deduction even as young as 4 years of age.

However, other researchers have suggested that good performance alone is not strong enough evidence of true syllogistic and deductive reasoning capabilities. Markovits, Schleifer, and Fortier (1989) claimed that until children are capable of demonstrating an explicit recognition of the structure of syllogisms, and can apply this deductive reasoning knowledge to more complex syllogisms - such as *'illogical syllogisms'*, where the premises are unconnected - then it cannot be claimed that they are truly capable of deductive reasoning. They presented children between the ages of 6 and 11 years old with a series of matched fantasy syllogisms which were either logical (e.g., "Every Zobole is yellow. All yellow things have a nose. Do Zoboles have a nose?") or illogical (e.g., "Every Zobole is yellow. All red things have a nose. Do Zoboles have a nose?"). Findings confirmed that the youngest subjects (6 year olds) gave similar responses and justifications to both logical and illogical syllogisms, and even the 11 year olds were not consistent in their ability to explain the reason for their responses with the illogical syllogisms. Markovits et al. (1989) argued that such a finding demonstrates that young children are not truly capable of logical deduction, and that rather they are reasoning according to a low-level matching strategy, which falls short when applied to illogical syllogisms. The evidence suggests a developmental improvement and shift towards understanding of the distinctions between logical and illogical syllogisms by 11 years of age, but Markovits et al. (1989) claim that even at this age children are not fully in possession of logical reasoning ability since they are unable to explicitly describe the reasoning process.

Evidence such as the above suggests that at 4 years of age, children are not capable of truly deductive reasoning, although they may be exhibiting the beginnings of a reasoning capacity which will develop into a full ability by their early teens. This idea takes us back to Piaget (e.g., 1928) and his claims that children would be incapable of deductive reasoning until around 12 years of age, because until then they are unable to consider hypotheticals and can only reason on the basis of direct observations and empirical knowledge.

However, not all research has led to an acceptance of the claims such as those posited by Markovits et al. (1989), and other researchers have suggested that requiring the child to *explain* the reasoning process is too strict a criteria for judging their competence. English (1993) conducted a range of experiments aimed at confirming the young child's deductive reasoning capacity, both with logical and illogical syllogisms. She presented 5 and 6 year old children with a series of fantasy syllogisms set within a make-believe context (half with toy actors, and half child play without props), some of which contained information that was congruent with the child's empirical knowledge, and some which were incongruent. She also examined the effect of pragmatic links between the premises, following up on the finding by Hawkins et al. (1984) that pragmatically unconnected syllogisms proved harder for the subjects. An example of a pragmatically-related fantasy syllogism would be:

> Every Bongo likes to lie in the mud.
>
> Animals which lie in the mud have dirty teeth.
>
> Wally is a Bongo.
>
> Does Wally have dirty teeth?

An example of a pragmatically-unrelated fantasy syllogism would be:

All Kooloos dance when it rains.

Animals that dance do not like pizzas.

Tammy is a Kooloo.

Does Tammy like pizzas? (English, 1993, pp.407)

English (1993) found that, out of a total of 58 responses to the syllogisms, a mean of 46.1 were both correct and explained with a theoretical justification. There was a tendency for the younger children to give more empirical justifications when the syllogisms were pragmatically unrelated, supporting the findings of Hawkins et al. (1984), and children also performed more accurately if given the toy-play condition before the no-prop play condition. However, English claimed that even with these slight differences in performance, evidence suggests valid deductive reasoning by the subjects. In order to strengthen this claim, she followed up the first experiment by presenting fantasy and counterfactual syllogisms to children aged 7-11 years, half of the syllogisms being logical and half being illogical. Again the syllogisms were presented in a pretend/play context, with the children being shown pictures that related to the characters. She found that the children still performed well, with a high correlation between correct responses and theoretical justifications, and, moreover, the children were not giving equivalent responses to illogical syllogisms as to logical syllogisms, contrary to the findings by Markovits et al. (1989). English proposed that this was due to the fact that the illogical syllogisms used in her study were not matched in design to the logical syllogisms. She claimed that the finding by Markovits et al. (1989) was biased by the fact that those syllogisms were matched, and that when children are presented with dissimilar illogical and logical syllogisms, they demonstrate an implicit understanding that the illogical syllogisms are structured differently to the logical syllogisms.

In concluding, English (1993) reaffirmed her belief that young children are capable of demonstrating deductive reasoning when the context in which the syllogism is presented is such that real-world knowledge does not interfere with the information in the syllogisms. She stated that children of 7 years of age could implicitly distinguish illogical and logical syllogisms, and that the poor performances in explaining the distinctions found by Markovits et al. (1989) were due to the young child's difficulty in explicitly expressing such cognitive processes, rather than through a lack of the implicit presence of such processes.

The studies reviewed here in general suggest that young children are beginning to show prowess at logical deduction even as young as 4 years of age, provided that they are assisted in ignoring irrelevant real-world knowledge, and that by 7 years of age this ability has advanced such that more complex syllogisms are being tackled. Perhaps the ability to perform well on very complex logical problems does not develop in full until around 11 years of age, but this is perhaps due to the nature of the tasks, rather than a lack of logical capacity on the part of the young child. Many adults would struggle with degree-level maths, but this does not prove that they are incapable of performing mathematical calculations. Evidence seems to point conclusively to a blossoming logical reasoning capability from around 4 years of age in normal development.

So far this review has explored only normal reasoning development. The findings point to an inferential capacity developing first at around 2 to 3 years of age, and that by 4 years of age children are capable of analogical and logical deductive reasoning in circumstances where the task contexts are designed not to lead to confusion on the part of the child.

The theories surrounding the cognitive processes that underlie logical reasoning in general cover two main camps - the argument that reasoning is performed via a set of propositional, logical rules which could be either abstract in nature, or based on concrete knowledge; and the argument that reasoning is performed through the use of mental models of some kind. It seems sensible to suggest, as did Roberts (1993), that perhaps there is an element of mental models *and* logical rules through which we reason. Perhaps one uses past experience or understanding about the real-world to model the problem originally, and adapts this according to the relevance of the information in the problem, and as more experience is gained in reasoning such problems - whether in day-to-day situations, or in school tests, or intelligence tasks - cognitive rules and guidelines are formed which can be flexibly applied to further problems in the future. Nevertheless, whatever the ongoing debate about the nature of the cognitive processes involved in reasoning, it is clear that skills are emerging in normal development between 2 and 4 years of age, which continue to get more advanced as the child grows.

Having explored the literature concerning normal reasoning development and before going on to describe some experimental studies testing reasoning in autism, this review will turn now to those studies that have explored reasoning performance outside the normal population, and especially in autism.

3.3: Reasoning in Autism and Mental Handicap

There appears to be very little research to date which explores performance by children and adults with autism on tasks such as those reported in the previous section with normal populations. Much of the research that has been conducted into reasoning ability has included this as part of a wider intelligence testing, and thus has not concentrated specifically on various types of reasoning. Nevertheless, this review will examine the studies that have been conducted in any area of reasoning with autism, to draw some comparisons with normal development, and with research into non-autistic but mental handicapped populations.

3.3.i: Cognitive Inflexibility in Autism

It seems sensible to suggest that in order to be able to perform tasks of reasoning, one needs a degree of flexibility of thought to deal with the application of rules, schemata, or models to the problem, and to adapt them as appropriate. If a specific set of rules, for example, or a rigid kind of cognitive model, was always used in exactly the same way each time a reasoning problem was confronted, the outcome would invariably be the drawing of invalid conclusions. In order to perform across a variety of reasoning tasks, one needs to be able to consider each task individually, and to apply the relevant knowledge, whether experience or rules, to that task as necessary. Many researchers have suggested that in autism, flexibility of thought is deficient. The executive dysfunction hypothesis of autism, outlined in Chapter 1, bases the main part of its arguments on the claim that people with autism have difficulty shifting cognitive sets, planning actions, and in other areas that require cognitive flexibility.

Ozonoff, Pennington, and Rogers (1991) compared subjects with autism and clinical controls on several measures of executive function, theory of mind, verbal memory and emotion perception tests. They found significant differences in performance on the executive function Tower of Hanoi task, although there were no differences in the Wisconsin Card Sorting Task. The first of these tasks examines planning whereas the second concentrates on shifting of cognitive sets. (Differences were also found in theory of mind, but that is of little immediate relevance, as the arguments were outlined in Chapter 1). This finding was suggested to imply a deficit in cognitive flexibility, which was supported in another study (Ozonoff, Strayer, McMahon, and Filloux, 1993) where subjects were presented with a series of tasks requiring cognitive flexibility and inhibition of prepotent responses. The subjects with autism performed significantly worse than the control subjects (normal and Tourette Syndrome) on such tasks.

Rumsey and Hamburger (1988) gave adults with autism a variety of neuropsychological tests, and found their performance on problem-solving tasks to be impaired relative to controls. These tasks included Binet absurdities - both pictoral and verbal - a task which is claimed to measure reasoning ability as well as problem solving. However, the control subjects used by Rumsey and Hamburger (1988) did not include mental handicap controls, only normal adult controls, so it is hard to ascertain whether the results are autism-specific.

A similar study by Carpentieri and Morgan (1994), which examined performance by children with autism and mental handicap controls on subtests of the Stanford Binet intelligence scale. These subtests included vocabulary, comprehension, absurdities, quantitative ability, pattern analysis, copying, bead memory, and memory for sentences. They found that the children with autism performed significantly worse on the tasks involving verbal reasoning, especially the absurdities task. However, Carpentieri and Morgan point out that the absurdities subtest assesses *social knowledge* as well as the ability to relate life experiences, and since social understanding is an area with which individuals with autism have severe deficits, it is not surprising that they performed less well than controls. Also, Carpentieri and Morgan (1994) found that the children with autism performed *better* than the control group in the area of quantitative reasoning - solving problems about numbers, for example.

These findings suggest that while there may be evidence of some form of cognitive inflexibility in autism, the evidence as yet does not demonstrate that this is autism-specific, nor does it demonstrate that it includes reasoning skills. There have been almost no studies explicitly of reasoning with subjects of autism, and what little has been reported within the wider intelligence and neuropsychological tests shows little evidence of a deficit in that area when other confounding influences (such as social thinking) are taken out. (The experimental studies reported in the next chapter of this thesis are intended to fill this gap).

Minshew, Siegel, Goldstein, and Weldy (1994) studied the verbal problem-solving and abstract reasoning ability of adults with autism and normal controls on a task where the subjects were required to ask up to 20 questions about common objects on a grid, in order to work out how to group them, and which went with which. They found that the subjects with autism performed poorly, relying mainly on guessing, and claimed that this demonstrated a deficit in abstract reasoning. This study is unique in that it has attempted to study reasoning specifically. However, again the controls are only normal controls and therefore it is not possible to say whether the results show a specific deficit to autism. In addition, if there is a deficit in the ability to shift set flexibly, then this, rather than reasoning ability, may account for the results.

3.3.ii: Inferences and Categorisation by Children with Autism.

In the earlier part of this review, it was suggested that in normal development children start to infer relationships between category members when learning about hierarchies at around 2 years of age. There has been some research into the performance of children with autism and matched controls with mental handicap, compared to normally developing children, in categorisation. The majority of this work has been conducted by Helen Tager-Flusberg (e.g., 1985a; 1985b; 1986). Tager-Flusberg demonstrated, through a series of experiments, that children with autism performed as well as mental-age-matched normally developing children and mental handicap controls both in their ability to categorise pictures from basic and superordinate levels (1985a) - where all 3 groups found basic-level categorisation easier than more abstract categorisation, and found prototypical examples of superordinate categories easier to categorise - and in their ability to understand words used for basic and superordinate categories (1985b) - where all 3 groups showed the same error patterns of overextension and underextension relating to prototypical examples of concepts. Tager-Flusberg argued that findings such as these demonstrate that children with autism acquire a conceptual system and process semantic information in the same way as other groups of children (1986, pp.79), and that perhaps their cognitive deficits are related more to an inability to use cognitive representations flexibly (e.g., 1985b).

3.3.iii: Higher-Level Reasoning and Autism

To date, studies of reasoning which examine the performance by children with autism on tasks of analogical, deductive, or syllogistic reasoning of the kind that have been used with normally developing children, have not been conducted. Nor have there been any studies exploring the performance by children with autism on *transitive* inferential reasoning, which, unlike inferences in categories, seems to also develop around 4 years of age in normal development.

Some work has explored the performance by children with mental handicap on analogical reasoning tasks such as those used by Goswami (1989), and has found that children with mental handicap are capable of reasoning by analogy, but to a lesser level of performance than normal 5 and 6 year olds (Robertson, 1993). However, this remains the only study directly comparing abnormal development with normal development in reasoning performance. Since reasoning ability could have important consequences on theory of mind task performance, and on executive dysfunction arguments regarding cognitive processes and weak central coherence hypothesis, as well as widening understanding of both normal and abnormal cognitive processes, it seems important to address some of the problems mentioned here. The next chapter reports experimental work that explores performance by children with autism, and matched mental handicap and normal controls, on tasks of transitive inference, analogical reasoning, and syllogistic reasoning.

CHAPTER FOUR

Three Experiments Exploring Abstract Reasoning in Autism.

4.1: Experiment 1 - A Study of Transitive Inference in Autism.

As noted in Chapter 1 the majority of children with autism fail classic theory of mind tasks, despite their chronological and verbal mental ages being well above the normal requirement for success (Baron-Cohen, Leslie, and Frith, 1985; Leslie and Thaiss, 1992; see Baron-Cohen, Tager-Flusberg, and Cohen, 1993). However, a common factor in many theory of mind tasks is that they require the subject to employ complex reasoning. The subject has to work out a logical relation between the events that he or she perceives, and then draw a conclusion based on that relation. For example, the subject may have to reason that Sally didn't *see* her marble being moved, *therefore* she won't *know* its new location. In principle, then, a subject could fail theory of mind tasks because of being unable to reason about relations. On the other hand, if the theory of mind impairment in autism is specific, then children with autism should have no problems on abstract logical reasoning tasks that do *not* require reference to mental states.

Experiment 1 in this chapter explored reasoning ability in children with autism, and matched controls, with a task of Logical Reasoning. The task tested Transitive Inference, and was based on the seminal study by Bryant and Trabasso (1971). Transitive Inference was chosen because to succeed in the task requires reasoning of an abstract nature (i.e., reasoning about relations), yet the task does not involve mental state attribution. Also, Bryant and Trabasso (1971) demonstrated that such a task is within the ability of normally developing children of around four years of age, the age at which children demonstrate success with traditional theory of mind tasks. Thus, the reasoning task does not require the subjects to perform above the developmental level tapped by tests of theory of mind. A final reason for selecting the task derives from the structure. In the Transitive Inference task, subjects have to reason logically about *relations* between items (A>B, B>C, C>D, D>E; therefore B>D). Given that the theory of mind tasks require reasoning about *psychological relations* (between people), this study enabled a test of whether the difficulty for children with autism on theory of mind tasks was due to relational reasoning per se.

In summary, the relational reasoning hypothesis predicted that children with autism would show deficits in performance, relative to controls, if their theory of mind deficit was a consequence of a more general underlying deficit in abstract reasoning. In contrast, the theory of mind hypothesis predicted that reasoning about mental states would be selectively impaired in autism, whilst 'non-mentalistic' relational reasoning would be largely intact.

4.1.i: Method

Subjects - The subjects were as described in detail in Chapter 2. All those subjects listed for experiments 1 to 3 took part in this experiment.

<u>*Design and Procedure*</u> - The experimenter first showed the subject some drawings of pairs of objects, where one was always longer than the other, and asked the subject "Which is the longest x?", (pencil, for example). This was done in order to ensure that all the subjects understood the term 'longest'.

The experimenter then showed the subject the Transitive Inference equipment (which consisted of an upright, black wooden block containing 5 rods of the same diameter, but which differed in colour. All 5 rods protruded 1" from the block, but were actually all different lengths, thus it was impossible for the subjects to tell from looking which rods were the longer), and told the subject that (s)he was going to play a game where (s)he had to try to work out which rod was the longest.[2] The Transitive Inference equipment was then removed from sight.

The Task had 2 phases: In the *Training Phase*, the experimenter showed the subject the Transitive Inference equipment containing two adjacent rods, and asked him/her to point to the one (s)he thought was the longest. Subjects were not allowed to take the rods out, so they had no visible way of telling which rod was the longest, since all rods protruded an equal amount from the block. The only visible difference between the rods was that each was a different colour. After the subject had made a decision, the experimenter said "Well done! Yes, the (colour of rod) rod is the longest" or "That's a good try, but the (colour of rod) rod is the longest", depending on whether the subject chose correctly or not. The Transitive Inference equipment was then removed from

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2 Each subject was actually asked what he/she would call the 'rods' used in the Task, so that the Experimenter could then refer to them in a way that the subject would understand. For simplicity, they will be referred to as 'rods' here.

sight, and the pairing of rods was changed to the next pairing, before being presented again to the subject. During the Training Phase the subject was presented with the rods in pairings AB,BC,CD,DE. The experimenter always told the subject which was the longest after the subject had made a choice, and the pairings were repeatedly presented until the subject could consistently pick the longest rod each time.

In the *Test Phase*, the experimenter presented the subject with 10 pairings of rods, 6 of which required an inference (AC,AD,AE,BD,DE,CE) and 4 of which only required memory (e.g., AB). During this phase the experimenter did not give any feedback concerning the lengths of the rods. The subject was given each test pairing once only, in randomized order.

<u>4.1.ii: Results</u>

All subjects across groups passed the control questions concerning the meaning of the term 'longest'. Therefore all subjects were given the Transitive Inference task. Table 4.1 illustrates the percentages of subjects in each group who passed the test questions, and also the percentage of subjects in each group who failed 2 or more memory questions. Whilst the subjects with autism performed significantly worse than the normal children in their ability to pass all 10 test questions (Chi-Square = 6.6, $p<0.01$), they were not significantly worse than the mental handicap controls (Chi-Square = 0.53, $p<0.5$). Furthermore, when the subjects with autism who failed at least 2 of the 4 memory questions, and who therefore may not have remembered the original training lengths, are excluded from the analysis, the difference in performance between subjects with autism and normal controls is no longer significant (Chi-Square = 3.01, p>0.1).

TABLE 4.1: Transitive Inference Test, % of subjects passing test questions.

Subjects	% pass all test q's	% pass 6+ test q's	% pass critical BD	% fail 2+ memory q's
Autism	35.3**	76.5	64.7	17.6*
M.H.	60	80	66.7	13.3
Normal	88.2	100	88.2	0

* Chi-Square, p<0.05 (Autism x Normal)

** Chi-Square, p<0.01 (Autism x Normal)

There was no significant difference between groups for subjects passing at least 6 out of 10 test questions (Autism x Normal, Chi-Square = 2.55, p=0.11; Autism x Mental Handicap, Chi-Square = 0.04, p=0.85; Mental Handicap x Normal, Chi-Square = 1.77, p=0.18), and when the critical BD inferential question was examined (this being the one question that Bryant & Trabasso (1971) argue to be truly inferential), again there was no significant difference between groups in their pass rates (Autism x Normal, Chi-Square = 1.62, p<0.1; Autism x Mental Handicap, Chi-Square = 0.06, p<0.75; Mental Handicap x Normal, Chi-Square = 2.17, p<0.1, see Appendix 1). Thus, children with autism do not show a strong deficit in their ability to perform transitive inferential reasoning of this kind.

4.1.iii: Discussion of Experiment 1

This first experiment suggests that on the basis of the critical BD, compared to children with general mental handicap but no autism, children with autism are comparable in their ability to reason by transitive inference. This finding thus suggests that poor performance with tests of theory of mind, for example, may not be due to an inability to understand the relations between items in the tasks, or to reason successfully about those relations. Rather, it suggests that performance may be due to some other factor, such as an inability specifically to understand mental states.

Results also raise questions concerning the executive dysfunction hypothesis, and the weak central coherence hypothesis of autism. Both of these hypotheses claim that some form of cognitive inflexibility, whether in a central executive or some related form of general information processor, underlies the deficits seen in children with autism. However, the evidence from this first experiment suggests that children with autism are at least comparable with children with mental handicap in their ability to consider the relations between encoded information in order to reason about previously unstated, inferential relationships - an ability that arguably requires both flexibility of thought, and encoding of information as related rather than separate pieces.

However, to draw conclusions on the basis of one experiment alone is far from prudent. In order to strengthen the argument that children with autism are truly capable of abstract reasoning, further experiments exploring other kinds of reasoning processes that are developed in normal 4 year olds are required. This chapter will now go on to report the findings from a second reasoning experiment, and will then compare the findings from these first two closely related experiments.

4.2: Experiment 2 - A Study of Analogical Reasoning in Autism

Experiment 1 tells us that the reason children with autism demonstrate poor performance on tasks of theory of mind is *not* a deficit in relational reasoning. But might it be due to a deficit in general abstract reasoning ability? By the age of 4 years old, the majority of normally developing children are demonstrating the ability to perform tasks of logical reasoning, such as reasoning by analogy (e.g., Goswami and Brown, 1989; 1990; Brown and Kane, 1988).

Analogical Reasoning, like reasoning by Transitive Inference, requires the subject to consider the logical relations between sets of information, and reason according to those relations. In the traditional analogical reasoning task, this takes the form of reasoning about the *higher-order* relations between items (A is to B as C is to D - or, in the standard notation A:B::C:D). Thus, as with the Transitive Inference task, this analogy task enables a comparison between performance on theory of mind task - which involve reasoning about higher-order psychological relations - and non-mentalistic reasoning about higher-order relations such as is demonstrated in analogical reasoning.

The experiment described here was based on the study conducted by Goswami and Brown (1989) with 4 year old normal children.

4.2.i: Method

Subjects - As with the transitive inference task, the subjects were as described in Chapter 2.

Design and Procedure - This task had 2 conditions. Subjects received one of these in a first session and the other in a second session (approximately 2 days later). The order of presentation was counterbalanced across subjects. Before the task started the experimenter told the subject that (s)he was going to play a game where (s)he had to choose the picture to complete the pattern.

Causal Reasoning Control condition. In this condition, subjects were shown sets of 3 pictures of objects, all of which had all been affected in the same way (e.g., pictures of things that had all been cut into pieces). The experimenter placed these 3 pictures infront of the subject, one at a time, encouraging the subject to name each picture as it was placed to ensure that (s)he recognised what was depicted. When the pictures had been named, the experimenter reminded the subject that they had to choose the picture that would make a pattern with those already laid out.

The experimenter then laid out 5 choice pictures one at a time, in a random order, below the first 3 pictures. Again, the subject was encouraged to name the pictures as they were presented. One of these pictures was the correct choice, since it depicted the instrument that *caused* what was shown in the first 3 pictures (e.g., a knife, which would be used to cut things up). The other 4 pictures depicted instruments that were irrelevant to the causal change. There were 8 sets of these causal patterns, and subjects were presented with all 8 (see Appendix 2).

Once the subject had chosen the one that they thought would make a pattern, they were then asked to justify their choice. This was to ensure that there was some reasoning behind the choice, rather than mere guessing. It also enabled an analysis of the kind of reasoning that was being used. The experimenter then said "Well done, that's the right picture because....", or "Well, that's nearly right, but I would have chosen this picture because...". In both instances the experimenter went on to *explain* why the choice was correct. (e.g., "...because these pictures show things that have all been cut, and this picture shows a knife which is used to cut things."). An explanation of this kind followed every trial. This condition thus ensured that the subjects understood the causal relationships depicted.

Analogy condition. In this condition subjects were again shown sets of pictures, and given the same instructions as in the Causal Reasoning Control condition. However, in this condition the first 3 pictures were not laid out together in a line. Instead, the first 2 were placed as a pair, with a space before the third picture. These pictures showed an object that was in its normal state, and then the same object after something had happened to it. For example, the first picture might be a playdough sausage (A), and the second picture the same playdough sausage but cut into pieces (B). The third picture then showed an apple in its normal state (C), and the forth slot was left empty for the subject to complete the sequence.

5 choice picture cards were presented to the subject, only one of which depicted the analogical solution (e.g., an apple that had been cut into pieces (D)); the other 4 choice pictures were distractors that were related to (C) in some other way: These were a correct causal change, but on the wrong object (E), the correct object but with the wrong causal change (F), a perceptually similar object (G), and a semantically related object (H). As in the Causal Reasoning Control condition there were 8 trials (see Appendix 3). The 5 choice cards were presented in random order.

The subject was encouraged to name the pictures as the experimenter laid them out, and after selecting a picture to make a pattern the subject was again asked to justify their choice. Their justifications were recorded and analysed later. As in the Causal Reasoning Control condition, the experimenter followed each trial with an explanation. All subjects received all 8 trials.

The distractor choices used in the task were designed to explore what kinds of errors the subjects were making, and if they consistently made more of certain errors. In other words, would subjects tend to make perceptually related errors (distractor (G)), or would they tend to choose pictures that depicted the correct object but the wrong causal change (distractor (F)), suggesting that they understood that something had to happen to the object, but could not make the analogical connection, for example.

Finally, the Causal Reasoning Control condition was included in order to check the subjects causal knowledge, and provide some training in this if it was less than perfect.

4.2.ii: Results

Subjects across all 3 groups performed virtually at ceiling in the Causal Reasoning Control condition of this task (Autism: 94% pass, Mental Handicap: 93.3% pass, Normal: 100%), showing that subjects understood the causal relationships which underlay the analogy trials. In the Analogy condition, because the subjects had to choose the correct analogical solution out of a choice of 5 distractors, the probability of a correct choice by chance on any one trial was $p=0.2$. Passing more than 2 out of the 8 trials overall would also be above chance ($p<0.04$). The percentage of subjects passing 2 or more trials, (up to those passing all 8 trials), is shown in Table 4.2 (see Appendix 4).

TABLE 4.2: Analogical Reasoning Test, % of subjects passing different numbers of trials.

Ss.	pass 2+	3+	4+	5+	6+	7+	8
Autism	94.1	82.4	76.5	58.8	17.6***	11.8**	11.8**
M.H.	100	86.7	86.7	86.7	73.3	53.3	40
Normal	100	100	88.2	82.4	82.4	70.6	53

** Chi-Square, $p<0.025$ (Autism x M.L.D.)

*** Chi-Square, $p<0.001$ (Autism x M.L.D.)

The subjects with autism performed well above chance on the analogical reasoning, since they showed no significant difference in performance for passing 5 or more trials compared to controls. However, they performed significantly worse than both mental handicap and normal controls for passing 6-8 trials (6+ trials, Autism x Mental Handicap, Chi-Square = 10.05, $p<0.001$; 7+ trials, Autism x Mental Handicap, Chi-Square = 6.31, $p<0.025$; 8 trials, Autism x Mental Handicap, Chi-Square = 4.8, $p<0.025$). An examination of the types of errors made by subjects showed that the subjects with autism were choosing the right object but the wrong causal change 85% of the time they made errors. For example, if presented with pictures of (A) a playdough sausage, (B) a playdough sausage cut into pieces, and (C) an apple, they might choose (F) a rotten apple, when making errors, instead of the correct analogical choice (D) an apple cut into pieces. This is compared to 53.8% of errors by the group with mental handicap, and 57.1 % of errors by normally developing children. This trend in the errors of subjects with autism suggests that more often they selected the same object as was in picture (C), rather than the one showing the analogical relationship. However, since they still performed above chance, it appears that children with autism are probably capable of reasoning by analogy.

4.2.iii: Discussion of Experiment 2

The results of this second experiment do lend support to the suggestion that children with autism are able to reason by analogy. Their performance on the task was well above chance, demonstrating an ability to understand the higher-order analogical relationships that underlie the analogies. However, their performance was clearly below that of the children with mental handicap, most noticeably in success at passing 6, 7, or 8 trials out of 8. Since subjects with autism were equally capable as both control groups in their understanding of the causal relations underlying the analogies, as demonstrated by their ceiling performance in the Causal Reasoning Control condition, why were they unable to perform accurately in as many analogy trials as the subjects with mental handicap and the normally developing subjects?

One possible explanation for the results is that children with autism have a tendency to be drawn to the perceptually salient pictures (i.e., both of the choice cards that depict a matching object to picture card (C) - (cards (D)), the analogically correct choice, and (F), the correct object but incorrect causal change), and are unable to inhibit their response in selecting the first one of these cards that they see. This explanation would tie in with the hypothesis postulated by Ozonoff, Pennington and Rogers (1991), and Hughes and Russell (1993; Hughes, Russell, and Robbins, 1994), among others, who argue that children with autism have an executive function deficit which leads to their failure to disengage from salient objects. On this account, they fail theory of mind tasks, for example, because they are drawn to the saliency of where the object really is. In this way it could be claimed that the subjects with autism in the present study were significantly worse than controls in passing 6-8 analogy trials because they were unable to disengage their attention from the saliency of picture card (F) in those trials where this card was by chance presented before card (D). Unfortunately, this possibility cannot be confirmed or denied experimentally, since no record was taken of the order in which the cards were laid out. Because the choice cards were distributed randomly, it is only with hindsight that one can see the benefit of making a note of how each set was presented to the subjects.

However, the subjects with autism were still well above chance level in their pass rate for the analogy trials, suggesting that if they have a tendency to select the first perceptually relevant card impulsively, this does not prevent them from passing many trials of analogical reasoning.

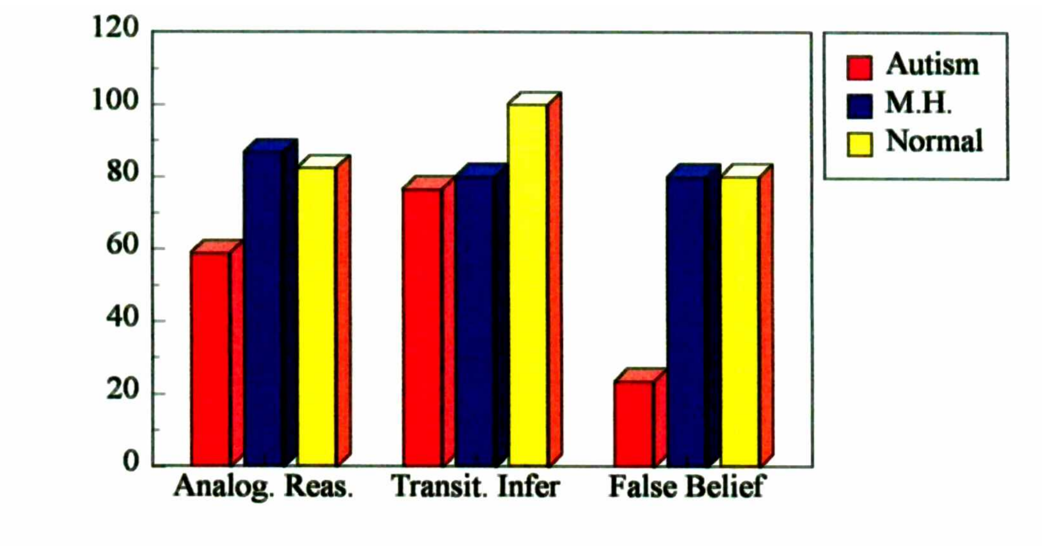
The fact that the subjects with autism performed well above chance suggests that the conclusions from experiment 1 were valid: children with autism and children with mental handicap are capable of demonstrating logical reasoning, although they are not as able as normally developing children, and this difference is as yet unexplained.

4.2.iv: Discussion of Experiments 1 and 2 - Logical Reasoning compared with Theory of Mind.

It is of interest to compare the above results with performance by the group with autism on a standard False Belief Task, the Sally-Anne Task (Baron-Cohen, Leslie, and Frith, 1985). All of the sample of children with autism were assessed on this task (Charman and Baron-Cohen, in press) within 3 months of the present experiments. The results are reported here with permission. Only 4 out of the 17 children with autism (or 23.5%) passed this theory of mind test. This proportion is significantly fewer than those passing either the Transitive Inference Test (Chi-square = 11.11, $p>0.001$) or the Analogical Reasoning Test (Chi-square = 8.17, $p>0.01$). This within-group difference is shown in Figure 4.1.

Figure 4.1: Comparing Analogy, Transitive Inference, and False Belief.

Percentage of each group passing each test
(Pass AR = 5+; Pass TI = 6+)



The first two reasoning experiments reported here concentrated on two competing hypotheses: (1) that children with autism demonstrate poor performance on theory of mind tasks because they have a specific deficit in understanding mental states; versus (2) their theory of mind deficit is the result of a more general deficit in abstract relational reasoning.

The relational reasoning hypothesis was apparently refuted: subjects with autism were comparable to matched clinical controls on both Transitive Inferential and Analogical reasoning. It would appear probable, then, that the deficit in autism is specifically related to Psychological Reasoning. This is support for the "mindblindness" account of autism (Baron-Cohen, 1990; 1995) - that children with autism are 'blind' to the understanding of their own and of others mental states. However, this does not rule out that mindblindness is secondary to some *other* cognitive ability not directly tested here.

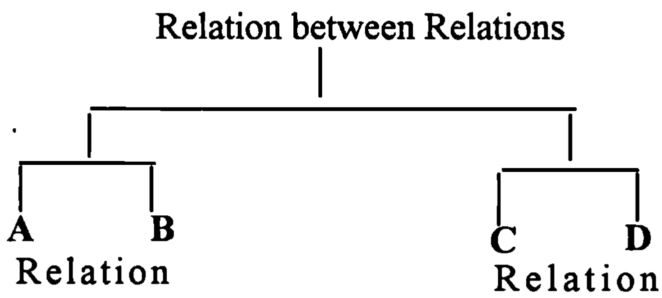
As has been described in Chapter 1, and briefly mentioned in the preceding discussions, Frith (e.g., 1989; Frith and Happe, 1994) has proposed a "weak central coherence theory". This holds that children with autism may have a deficit in their ability to see information as an integrated whole, and instead tend to focus more on the separate parts. They lack the normal drive for Gestalt perception, and instead of seeing the forest but not the trees (as a normal individual does) they tend to see the trees but not the forest. Frith (1989) suggests that this lack of strong central coherence leads to their superior performance on the Embedded Figures Task (e.g., Shah and Frith, 1983), and on Block Design (Shah and Frith, 1993), as well as explaining their difficulties with theory of mind tasks. This account would predict that they should be less able to make relevant connections between pieces of information. However, the results of the present studies suggest that children with autism *are* capable of making relevant connections between several pieces of related information. If there is weak central coherence in autism, it is not pervasive, as it does not prevent logical transitive inference, across relations, nor a degree of analogical reasoning about higher-order relations.

The structure of the Analogical Reasoning task, and the reported performance by children with autism has implications for Leslie's modular theory of theory of mind (ToMM) (Leslie, 1987;1991;1994). As mentioned earlier, the Analogical Reasoning test involves reasoning about higher-order relations. In looking at picture cards (A), (B) and (C), there are many possible connections. In order to complete the analogical pattern, the subject has to be able to consider the relation between (A) and (B), and understand that *that relation* has to be represented in relation to that between (C) and (D). Thus, it is not enough to understand the relation between cards (A) and (B) alone, and the relation between (C) and (D) alone. If the subjects were unable to represent the higher-order relation, then they would pair any of the distractors with card (C) randomly, since all 5 distractor cards are related to card (C) in some way.

Since the children with autism perform well above chance on the Analogical Reasoning task, this ability to represent higher-order relations between stimuli raises questions in relation to Leslie's (1987) and also Perner's (1993) theories of the 'metarepresentational' deficit in autism.

Roth & Leslie (1991) suggest that children with autism are capable of creating primary representations of the world, that is, they can directly represent objects, situations, and real-world scenarios, but they suggest children with autism are unable to represent an agent's attitude to a proposition (a so-called M-representation). In contrast, Perner (1993) suggests they are unable to represent representations of representations (or 'metarepresentations'). One reading of Perner's theory would predict that children with autism should be *unable* to pass the Analogical Reasoning task, since this involves representing a higher-order relation which in itself is a representation of the two lower-order representations (see Figure 4.2).

Figure 4.2: Representing a higher-order relation in analogies.



Since the present results show evidence of subjects with autism reasoning with representations of representations, this suggests that the deficit in autism is unlikely to be a general deficit in metarepresentational ability, as Perner maintains. Rather, the results are consistent with Leslie's modular view that there is a deficit in the representation of mental states alone. Such a conclusion is consistent with a series of independent studies showing that children with autism can represent non-mental representations such as drawings, photographs, maps, and models (Leekam and Perner, 1991; Leslie and Thaiss, 1992; Charman and Baron-Cohen, 1992; in press) whilst still failing on tasks requiring the representation of mental representations. The results of the present experiments take us one step further in suggesting that the cognitive system that is impaired in autism is not involved in logical or analogical reasoning, but appears to be dedicated to psychological reasoning (Baron-Cohen, 1994). This is consistent with claims by Cosmides & Tooby (1989) and Brothers (1990) that specific brain systems may have evolved to solve specifically *social* and *intentional* problems. Children with autism may show us the limitations of a cognitive system capable of non-social logical reasoning, but severely impaired in social-psychological reasoning.

However, a claim such as this requires further experimental evidence to support it. The previous experiments, 1 and 2, have suggested that children with autism may be capable of analogical reasoning and transitive inferential reasoning, and that this involves a cognitive system that is separate from that involved in the understanding of mental states. The following experiment again explored logical reasoning at a level that is competently handled by normal 4 year old children - that is, deductive syllogistic reasoning. However, this experiment also incorporated additional variables that relate to the diagnosis of autism: (1) the syllogisms presented were based on information that was counter to fact; and (2) a condition was included that explored the effects of mental imagery or imagination. Imagination is counted as a 'mental state' (e.g., Gopnik and Slaughter, 1992), and is believed to be impaired in autism, yet has received little experimental study in autism research.

4.3: Experiment 3 - Syllogistic Reasoning in Autism: The Effects of Counterfactuals and Imagination.

Children with autism show a tendency to be very literal in their thinking and understanding (Frith, 1989; Kanner, 1943). For example, when told that his sister had cried her eyes out, one child with autism immediately started to search the carpet for his sister's eyes (Baron-Cohen & Bolton, 1993, p.50). Such clinical anecdotes suggest that children with autism may treat all statements as factual. If children with autism are only able to deal with information in a factual way, then this might explain why these children give reality- based answers in theory of mind tasks (for example, with the traditional false-belief task, saying that Sally will look for her marble in the box that it is *really* in). It would also mean that they should be unable to comprehend counterfactual statements. Experiment 3 therefore explored if children with autism were still capable of demonstrating reasoning capabilities when presented with counterfactuals. Can the subjects with autism understand syllogisms that are counter to reality?

Also, as mentioned, it is widely accepted that children with autism lack imagination, and yet there is little or no empirical evidence that has examined their imagination per se. If children with autism do have an imagination deficit, this could explain why they exhibit virtually no pretend play (Leslie, 1987; Baron-Cohen, 1987; Jarrold, Boucher & Smith, 1993). It could also explain why they perform so poorly on theory of mind tasks, since one could argue that in order to pass these tasks it is necessary to "imagine" what someone else is thinking. Thus, the third aim of the present study was to explore the imaginative ability of children with autism.

To explore deductive reasoning, counterfactual understanding, and the effect of imagination in a single experiment the method used was based on a study by Dias & Harris (1990), which involved presenting subjects with counterfactual syllogisms, and which also incorporated a condition where the child's creative imagination is prompted and its effect on reasoning explored. Dias & Harris (1990) found that 4-6 year old normal children showed poor performance when reasoning with counterfactual syllogisms. However, when the children were encouraged to "imagine" unusual things (such as a flying pig), and then were instructed to use their imagination in the task, their performance improved dramatically.

In the present experiment, 3 predictions were tested:

(1) First, to support experiments 1 and 2, deductive reasoning ability was tested. If there is a deficit in abstract reasoning, then children with autism should be impaired, relative to controls, on the syllogistic reasoning task.

(2) Secondly, if subjects with autism are very literal in their thinking, then they should find the counterfactual statements hard to accept.

(3) Finally, if the primary deficit is in the use of imagination, then the subjects with autism should only show an abnormality in the condition which tested the effects of imagination on reasoning.

4.3.i: Method

Subjects - The subjects in experiment 3 were again as reported in Chapter 2, subjects for experiments 1 to 3.

Design and Procedure - Subjects were seen individually by the experimenter, in a quiet room. The experimenter told the subject that they were going to hear some little stories about things that were very different. Each subject was then asked a series of 10 Reality control questions in order to check for relevant general knowledge about the themes of the later stories (e.g., "Can you tell me what noise cats make?") (These questions are listed in Appendix 5).

The task had two conditions (Verbal Only, or Verbal plus Imagery), and each subject received both of the conditions, in different sessions and with at least a one month interval between each. Half the subjects received the Verbal Only condition first, and half received the Verbal plus Imagery condition first. These are described next.

Verbal Only - In this condition, after answering the Reality control questions and being reminded of the instructions, the subject was then presented with 5 counterfactual syllogisms, one at a time, spoken by the experimenter in a neutral tone of voice (See Appendix 6). After hearing the premises (e.g., All cats bark; Rex is a cat) the subject was asked to repeat them to ensure that they had been heard correctly. (If they were not repeated correctly the experimenter repeated the premises). The experimenter then went on to ask the Conclusion question (e.g., Does Rex bark?). After the subject had responded, he or she was asked to justify their answer, and the experimenter recorded their Justifications. These were later coded into (a) Theoretical, (i.e., based on the contents of the syllogism), (b) Empirical (i.e., based on the subjects knowledge of the real world), or (c) Arbitrary (i.e., random, irrelevant, or obscure). [3]

Verbal plus Imagery - In this condition, after answering the Reality control questions, the subject was led through a set of 7 Imagination Training and Imagination control questions, described here:

1. Can you make a picture in your head of a pig?
2. Can you make the pig do something different/funny?
3. Can you make the pig in your head fly?
4. Is the pig in the air, or on the ground? (The order of choices was counterbalanced).
5. What is the pig doing?
6. Is the pig real, or in your head? (Again, the order of choices was counterbalanced).

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3 An example of a Theoretical justification would be "Because you said all cats bark" An example of an Empirical justification would be "Because cats don't bark!"

7. Can *I* see the pig in your head?

These questions were intended to prompt the child's imagination, and at the same time test what the child understood about the nature of imagination. When the subject had answered all of these questions, and their responses had been recorded, the experimenter then repeated the original instructions, but this time adding that the subject should try and make a picture in his or her head about each of the stories. The subject was then told the 5 syllogisms (see Appendix 7), which were again spoken by the experimenter in a neutral tone of voice. As in the Verbal Only condition, the experimenter first tested if the subject could remember the premises, and also checked the child was attempting to visualize each story. The experimenter then asked the Conclusion question, and again asked the subject to justify his or her answer. As before, the child's justification was recorded, and later coded into the same 3 categories.

4.3.ii: Results

Reality control questions - All subjects, in each of the three groups, passed the ten Reality control questions without any difficulties.

Verbal Only Condition - Table 4.3 shows the number of subjects passing varying numbers of trials, (defined as passing the Conclusion questions of the syllogisms). It is clear that more subjects with autism passed five trials than either of the control groups. This difference was significant (Autism x M.H., Chi-Square = 4.4, $p=0.036$). However, there was no significant difference between the 2 control groups (M.H. x Normal, Chi-Square = 0.02, p=0.89).

TABLE 4.3: Verbal Only Condition; Number of subjects passing different numbers of trials.

GROUP	Pass 0 trials	Pass 1 trial	Pass 2 trials	Pass 3 trials	Pass 4 trials	Pass 5 trials
Autism	2*	0	2	0	1	12*
M.H.	8	1	0	1	2	3
Normal	7	0	3	2	0	5

* Chi-Square, p<0.05

Verbal plus Imagery Condition - For this condition, results indicated a trend in the opposite direction. The control groups passed on a greater numbers of trials, whereas a high proportion of children with autism only passed 0-2 trials (See Table 4.4.) The differences between the 3 groups of subjects were not however significant (Autism x Normal, Chi-Square = 0.8, p=0.37; Normal x M.H., Chi-Square = 0.02, p=0.89).[4]

[4] Note that the range of the Verbal Mental Age of the subjects with autism was greater than that of the subjects with mental handicap This was due to one subject with autism who had a V M.A. of 120 months (10 years). All results were examined with and without the data from this subject, but it was found that his inclusion did not significantly affect the results.

TABLE 4.4: Verbal plus Imagery Condition; Number of subjects passing different numbers of trials.

GROUP	Pass 0 trials	Pass 1 trial	Pass 2 trials	Pass 3 trials	Pass 4 trials	Pass 5 trials
Autism	5	2	2	1	0	6
M.H.	5	0	0	1	5	3
Normal	2	0	3	1	5	4

A within-group comparison was carried out across the two conditions. This showed that the performance of the subjects with autism was opposite to the performance of both control groups. Thus, whereas the normal 4-5 year olds and the subjects with mental handicap both showed an improvement in their performance in the Verbal plus Imagery condition, the performance by subjects with autism was worse in the Verbal plus Imagery condition. This can be clearly seen in Table 4.5 below. These results thus show a cross-over between groups (See Figure 4.3). An examination of performance within groups show this cross-over to be significant: Autism, Verbal Only x Verbal plus Imagery, McNemar Chi-Square = 6, $p=0.01$., with significantly more subjects passing the Verbal Only condition. For the normal children, Verbal Only x Verbal plus Imagery, McNemar Chi-Square = 3.57, $p=0.05$., significantly more subjects passing the Verbal plus Imagery condition. For the children with mental handicap, Verbal Only x Verbal plus Imagery, McNemar Chi-Square = 2.67, $p<0.1$. This result did not reach significance, although the trend was still towards more subjects passing in the Verbal plus Imagery condition (see Appendix 8).

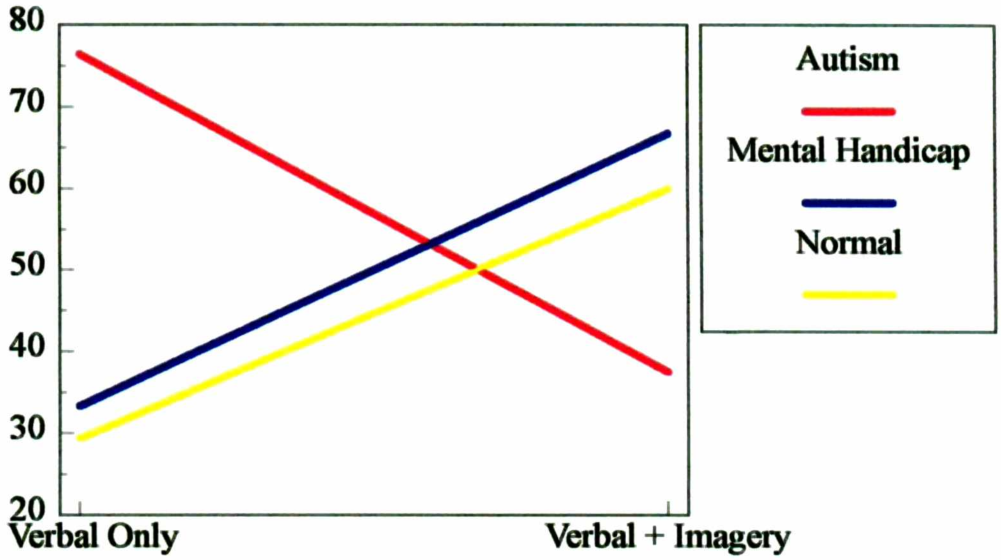
TABLE 4.5: Percentage of subjects passing at least 4 out of 5 trials, for each condition.

GROUP	VERBAL ONLY	VERBAL + IMAGERY
Autistic	76.5%	37.5%**
M.H.	33.3%	66.7%
Normal	29.4%	60.0%*

**McNemar Chi-Square p<0.01

* McNemar Chi-Square p<0.05

Figure 4.3: Counterfactual Syllogistic Reasoning Task
Percentage of subjects passing 4 out of 5 trials



The results of the Imagination Training and Control questions were also examined. Here it was found that the children with autism answered the questions concerning the location and nature of mental images only at chance level. Thus, whereas 92.9% of subjects with mental handicap and 100% of normal subjects reported that their mental images were in their heads, only 56.3% of children with autism did so. Also, 100% of normal 4-5 year olds reported that the experimenter could not see their mental images, as did 85.7% of the subjects with mental handicap, but only 43.75% of subjects with autism did so. In addition, the answers given by the subjects with autism did not reveal a robust understanding of imagery, since 44.4% of those who had answered the location question correctly then failed the question concerning whether or not the examiner could also see their images.

Regarding the instruction to think of pigs in "funny" situations, 100% of normal subjects, and 93% of subjects with mental handicap were able to do this. In contrast, 68.8% of subjects with autism could do this, but only when specifically *told* what to imagine. Rather, their spontaneous responses were in terms of pigs doing "normal" activities, such as going "Oink, Oink", or living in a pig pen.

Finally, the Justifications given by subjects regarding their answers to the Conclusion questions of the syllogisms were examined. It was found that all subjects gave Theoretical Justifications when they answered the Conclusion Question correctly (e.g., saying "Because you said that all cats bark, so Rex barks"), and Empirical justifications when they answered the Conclusion question incorrectly (e.g., saying "Because cats go miaow"). The only exception was one mental handicap subject with Downs Syndrome whose spoken speech was not as clear as her verbal comprehension, and who could only be scored as giving Arbitrary Justifications[5].

4.3.iii: Discussion of Experiment 3

This experiment set out to test three predictions. First, it was predicted that the children with autism should manifest deficits in logical reasoning if the theory of mind impairment was due to difficulties with abstract reasoning. This prediction was not supported. Rather, subjects with autism showed evidence of good logical reasoning ability in the Verbal Only condition, indeed, significantly better than that of the two control groups. The strength of this result is important in light of the slightly poorer performance demonstrated by the subjects with autism on the analogical reasoning task. It has been clearly demonstrated by performance in the Verbal Only condition of experiment 3 that children with autism *can* reason deductively, and thus the explanation posited for the poor performance in the analogies - that perhaps subjects with autism were drawn to the first perceptually related object they saw - has been supported, rather than the claim that they have a deficit in reasoning ability. This finding therefore lends further support to experiments 1 and 2, and also confirms other studies showing intact areas of non-theory of mind cognition in autism (Shah & Frith, 1983; Baron-Cohen, 1991b).

The second prediction of this study was that the subjects with autism should find counterfactuals hard to accept if they are very literal in their thinking. Again, this prediction was not supported as they performed so successfully in the Verbal Only

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5 The justifications provided by the subjects fitted clearly into each of the classifications. However, it could be argued that for some of the syllogisms, an apparently theoretical justification could be made without the subject having to consider both the premises (see Appendices 6 & 7) Since performances were no better for these syllogisms compared to others, however, this explanation is unlikely

condition. It is unlikely that this was due to these subjects ignoring the meanings of the premises, since they had no difficulty in giving theoretical justifications to their answers (e.g., "Yes, Rex barks, because you said that all cats bark."). However, one possible explanation for the success by children with autism in the Verbal Only condition is that they made no attempt to consider the premises as anything other than strings of words. These words are able to be related to each other, but do not necessarily from a *'meaningful'* sentence. To clarify this point, the children with autism may have been able to encode the premises as related pieces of information without encoding them as linguistically meaningful statements, similar to the way in which people deal with algebra, for example. When one is presented with the algebraic sentence "A plus B equals D divided by C", the relationships between the elements in the sentence can be calculated *without* the sentence being read as linguistically meaningful. Indeed, if one attempted to place any linguistic meaning onto such a sentence, it would clearly be nonsensical. It could be that a similar cognition is taking place with children with autism when they are presented with verbal syllogisms - they can relate the words in the premises, but they do not necessarily attempt to derive any meaning from them. In this way, when the subjects with autism are instructed in the Verbal plus Imagery condition to form a "Picture in the head" of what is described in the premises, they are forced to consider the premises in a *'meaningful'* way in order to imagine the scenario they are describing. In this condition they perform poorly, suggesting that perhaps there *is* a deficit in the understanding of counterfactuals. However, there are other possible explanations for this worsening in performance by the children with autism, which will be explored below.

The third prediction of this experiment was that children with autism would show an abnormality in the use of imagination on the reasoning task, if they have difficulties with either processing the logic of pretence (Leslie, 1987), or with mental imagery as a whole. This prediction was clearly supported. Whilst the two control groups improved their performance in the Verbal plus Imagery condition, replicating the results of Dias & Harris (1990), the children with autism showed *worse* performance in the Verbal plus Imagery condition.

One possibility for this performance is that in the Verbal Only condition the control subjects may have been unsure as to the experimenter's intentions, that is, unsure what on earth she was referring to, if not to reality. The inclusion of a set of questions that encouraged imagination of unusual things (such as flying pigs) may have clarified to the control subjects that the premises they were about to hear were *pretend*, and therefore not about reality. With this clarification about the experimenter's intention, namely, *pretending*, the subjects in the control groups were then able to show their true capabilities in logical reasoning of this kind. On this account, the failure by the subjects with autism to show such an improvement may either have occurred because of an impairment in their ability to create non-empirical mental images, or because of an impairment in understanding intentions.

Certainly, there is independent evidence that children with autism have difficulty in understanding intentions (Phillips, 1993; Roth & Leslie, 1991). Equally, the results from the Imagination Training questions suggested that these subjects could only imagine non-empirical images (such as flying pigs) when specifically instructed to do so, and that their spontaneous "images" were only of empirically correct situations.

Furthermore, nearly all the children with mental handicap and normal children understood that mental images are "just in the head", but only about half the children with autism answered this way. None of the normal and only 14% of the mental handicap children said the experimenter could see their mental images, but 56% of the children with autism said she could. This last result is all the more striking in view of previous findings showing that children with autism have no trouble determining when someone can and cannot see a physical *object* (e.g., Hobson, 1984; Baron-Cohen, 1989a; Leslie & Frith, 1988; Baron-Cohen, 1991b). Taking both questions together, only 37.5% of the children with autism answered correctly. One could argue that these two questions ("Is the pig real or in your head?", and "Can *I* see the pig in your head?"), are the most informative about the effects of the Training because the other questions could have been answered affirmatively without real understanding. In any case, it strongly suggests that the children with autism were confused about the ontological status of the mental states that were being talked about during the imagery training. If this is so, they would have been seriously confused as to whether, for example, the pig being talked about was real or not.

The difficulties of the group with autism on imagery training suggest that their poor performance on the Verbal plus Imagery condition could have been due, at least in part, to poor understanding of mental images as mental states. This could explain why training had opposite effects for normal children and children with mental handicap, on the one hand, and for children with autism, on the other. The imagery training, together with the invitation to answer each syllogism in this condition by constructing a mental image, may serve to clarify for the normal and the mental handicap children that what is being asked for are counterfactual "pretend" judgements, and not statements of fact. This could explain why the normal and mental handicap children did significantly better under these conditions than with similar problems presented in an "unadorned" way. In the Verbal Only condition, the normal and mental handicap children tended to answer with facts, as if they were suffering from "intrusions" or "executive functioning" difficulties (see e.g., Shallice & Burgess, 1991). Introducing the notion of mentally imaging unusual things seems to have helped the normal children and children with mental handicap overcome such errors. By contrast, talk of mental images may only have confused the children with autism, who performed well without it on the unadorned Verbal Only condition but then sank to a rather poor performance on the Verbal plus Imagery condition.

An alternative is that the children with autism become subject to intrusion errors only when they attempt to transform "normal" mental images into mental images of something unusual, like a flying pig. This is a more likely explanation than the simpler view that children with autism are unable to form and manipulate mental images *tout court*. Shah (1988) used standard tests of mental imaging ability, namely, Shepard's mental rotation tasks, and found that the children with autism performed as well as controls. Because mental rotation tasks require both the formation and manipulation of mental images, it is not likely that the children with autism were unable simply to form or manipulate mental images[6]. However, the possibility remains that they found it difficult to transform mental images of "usual" things into mental images of "unusual", counterfactual things, perhaps because of intrusion errors. On this account, normal and mental handicap children were subject to intrusion errors in the Verbal Only condition but not in the Verbal plus Imagery condition, while exactly the opposite was true for the children with autism.

It is not possible to tell from the data which of the above interpretations - "Mental State Misunderstanding" or "Creative Imagery Deficit" - is correct. It is even possible that both are correct simultaneously. For example, perhaps referring to mental images and transforming them in the service of solving the syllogism requires an ability not merely to entertain mental images but to introspect on them as well. If so, difficulties with understanding mental images as mental states will impact negatively on introspection and thus on the use of mental images in aid of counterfactual reasoning.

Finally, a further comment on the finding of excellent performance from the group with autism on the Verbal Only syllogisms. Contrary to what might have been assumed, children with autism do not appear by these measures to be impaired in verbal reasoning ability. This adds to evidence against the idea that verbal impairment explains "theory of mind" impairment, (see e.g., Baron-Cohen et al., 1985, and Leslie & Frith, 1988 for further evidence). It also makes it unlikely that a general impairment to counterfactual reasoning accounts for the "theory of mind" impairment. (Further evidence for this claim is provided by results showing excellent performance by

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6 Although it could be argued that some mental rotation tasks require the subject simply to manipulate information continually available to the perceptual system, without the need to generate an *unpromted* mental image. This may involve slightly different cognitive processes, and is a possibility that needs to be explored more fully in the future

children with autism on a variety of tasks which closely parallel the structure of false-belief tasks but which use pictures that go out-of-date rather than beliefs that go out-of-date. These out-of-date pictures represent a situation that is counterfactual, in that it is counter to the present fact. This definition of counterfactuality may be slightly different to that explored in the present study, which concentrates on the impossible, rather than on alternative but still *empirically possible* situations, and may involve different cognitive processes. (See e.g., Charman & Baron-Cohen, 1992; 1995; Leekam & Perner, 1991; Leslie & Thaiss, 1992).)

The present results caution researchers against assuming too simple a view of "imagination" as a single monolithic ability. The normal and mental handicap children looked as if they lacked "imagination" when given unusual verbal premises with which to reason. Even though they had been told they were "little stories", they simply responded with facts. At the same time, the children with autism were well able to treat these same verbal premises "imaginatively". However, when it was made clear to the normal and mental handicap children that imaginary states of affairs were being talked about, by inviting them to introspect on "pictures in their heads", it became clear that these children could indeed reason "imaginatively". The Imagination Training had exactly the opposite effect upon the children with autism, who appeared to be confused by these same instructions with the result that now their reasoning with verbal counterfactuals was disrupted by the intrusion of factual material. If this is right, further investigations of "imagination" should assume multiple, independent, or partially independent, mechanisms, not all of which are impaired in autism.

4.4: Summary and Conclusions of Experiments 1 to 3.

Let us reconsider the primary aim of this thesis, outlined in Chapter 1, to explore general reasoning ability by children with autism in tasks that do not involve theory of mind, and to ascertain whether there may be a general failure in complex reasoning, or a more specific failure in social reasoning, which explains performance on traditional theory of mind tasks.

Experiment 1 found that children with autism were no worse than controls in their ability to reason by transitive inference, critically in the BD inference. When presented with several pieces of information, children with autism were capable of making inferential connections and deductions from that information in order to provide answers to novel inferential problems.

Experiment 2 found that children with autism appeared comparable to controls in their ability to reason by analogy, making judgements about the higher-order analogical relationships between stimulii. Although the children with autism showed some deficit compared to controls for passing 6 to 8 analogies, their performance was still well above chance, and the possibility existed that in some cases the children with autism would choose an incorrect but perceptually similar choice object if it was presented to them before the analogical choice.

Experiment 3 confirmed that children with autism were capable of reasoning deductively, even when the information presented to them runs counter to fact, as results demonstrated that those subjects performed significantly better than controls in a verbal counterfactual syllogistic reasoning task. However, results also demonstrated that whereas control subjects improved performance when encouraged to use imagination, the children with autism performed much worse when encouraged to use imagination, and also showed a deficit in understanding the nature of mental images.

In the light of the primary aim of the thesis, these results suggest that children with autism do not have a general deficit for complex reasoning. The experiments presented were deliberately chosen to be both suitable for normal 4 to 5 year old children, and thus cognitively no more demanding than traditional theory of mind tasks which are also passed at this age, and also to explore a cross-section of reasoning types often examined in reasoning literature - inference, analogy, and syllogisms. With the subjects with autism showing comparable performance with matched clinical controls in all three areas of reasoning, it seems reasonable to assume that a deficit in reasoning is not fundamental to autism. It should also be noted that these experiments are equally as indicative of the capabilities of children with mental handicap in reasoning. These subjects have not been explored in any detail with reasoning tasks, and thus the experiments reported here offer new data on the cognitive abilities of these subjects with mental handicap.

These results give evidence to suggest that children with autism are *not* subject to the overwhelming degrees of cognitive inflexibility that have been postulated by some neurological researchers (e.g., Rumsey and Hamburger, 1987; Carpentieri and Morgan, 1994), or to a *general* weak central coherence deficit (Frith, 1989).

However, these results do give support to the possibility that children with autism have a specific deficit as applies to understanding of mental states (e.g., Baron-Cohen, 1990), and also that they may have a specific deficit in the area of mental imagery and/or imagination - tentative support for simulation theorists (e.g., Harris and Kavanaugh, 1993; Currie, 1990). It is the second of these two possibilities that will be explored in more detail in the remainder of this thesis. Before presenting experimental work exploring mental imagery and imagination in autism, the next chapter reviews research relating to imagery and imagination studies in normals and in subjects with autism and mental handicap.

CHAPTER FIVE

Mental Imagery and Imagination - A Review of the Literature

The findings from the Counterfactual Syllogistic Reasoning experiment (Experiment 3) reported in Chapter 4 raised a number of issues concerning mental imagery and/or imagination in autism. Before exploring the literature in these areas, it is important to clarify what these terms refer to in this thesis. "Imagination" covers many different kinds of thought depending on the context in which the term is used - it can refer to an ability to visualise ones self in a fantasy context such as on another planet, or to the ability to tell a good story, or form clear mental images in one's mind of past memories and events, for example. However, these things may all involve slightly different cognitive processes, even though the same term is frequently used to describe each of them. To explore only a limited area of "imagination" at a time, this thesis concentrates on the relationship between mental images and imagination. This is the most appropriate aspect of imagery to explore in relation to the experimental studies reported in this thesis, since the findings from the Counterfactual Syllogistic Reasoning experiment resulted from instructions to the subjects to "Make a picture in your head", and thus to use their imagination in a specific way. (It should be noted that mental imagery is not necessarily assumed to be specifically pictoral in nature, but is simply a form of representation that enables the subject to consider concepts in a depictive way - the analogue versus propositional debate will be outlined in this review chapter.)

Although the remainder of the thesis concentrates experimentally on mental imagery and its relation to imagination, this review chapter explores research both of mental imagery and of several aspects of imagination, including pretense, creativity and simulation. These aspects of imagination may also include elements of specific mental imagery, and the mental imagery experiments that will be reported in Chapter 7 may involve elements of creativity and pretense. As will be clear from the following review, imagery and imagination are intricately linked, and attempting to explore certain aspects of one also entails consideration of the closely related other.

The review starts with an exploration of mental imagery, looking at models of mental imagery and the propositional versus analogue debate. It is then followed by experimental and neuropsychological studies of mental imagery. Next is an examination of the literature on imagination, including simulation, pretense, and creativity. The final part of the review concentrates on studies of mental imagery and imagination with the two relevant clinical groups - autism and mental handicap. Following this chapter, five experiments are presented in Chapters 6 and 7 that explore mental imagery and imagination in autism and controls.

5.1: Models of Mental Imagery

There are two models of mental imagery that are perhaps the best known and most widely acknowledged in the field of imagery research. The first of these is the model proposed by Paivio during the 1960's and 1970's, and the second is the model that has been more recently developed by Kosslyn. The first of these models is described next.

5.1.i: Dual-Coding Theory

When Paivio (e.g., 1969; 1971; 1986) proposed his dual-coding theory of cognition, it contributed much to the re-awakening of interest in imagery research. In his theory he suggested two systems that underlay cognition - verbal and nonverbal - which, whilst independent of one another, are also very much interconnected. The verbal system is involved in the processing of linguistic information, and is thus argued to be specialised for sequential processing, whilst the nonverbal system processes nonverbal information and is specialised for analysis of scenes and for the generation of mental images. Both of the systems are proposed to have representational units specific to each system - logogens for the verbal system and imagens for the nonverbal system; and both systems are also sub-divided into sensori-motor subsystems (such as taste, touch, vision, etc.) each of which involve modality-specific variations of the basic logogen and imagen representational units. These representational units enable the interconnecting of the two systems via referential links (see e.g., Paivio, 1986, p.66).

The essence of the theory is relatively simple - there are two main systems involved in cognition, one which deals mainly with language and one which deals with anything nonverbal, and is encoded via mental images. When the symbolic units in the systems (logogens and imagens) are activated, they interconnect with one another. Thus, if one was to read the word 'Horse', for example, the logogens triggered would also stimulate related imagens of the appearance of a horse, or its smell, and so-on. In addition, Paivio (1971) suggested that the two hemispheres of the brain were specialised in preference towards either verbal or nonverbal processing. He suggested that the right hemisphere specialised in the processing of images, and the left in the processing of semantic material.

Paivio (e.g., 1971) provided experimental evidence to support his theory, demonstrating additive effects between the systems, as well as independence. For example, he presented subjects with lists of words, or with sets of pictures, which they had to memorise. Subjects tended to spontaneously name common items that were presented pictorially, and Paivio argued that this would entail both the verbal and nonverbal systems being activated, and thus produce better recall for those pictures. This was found to be the case. However, it is not clear whether common, more concrete objects are really easier to recall because they stimulate both coding systems, or purely *because* they are more concrete (e.g., Jones, 1988) and thus involve more detailed and fuller representation in long-term semantic memory.

Paivio and Csapo (1973) asked subjects to either repeatedly image a given word (noun), or repeatedly pronounce it, or alternate between imaging and pronouncing the word. (The repeated word was included in a set of many words with which the subjects were presented, and was not repeated consecutively.) When the subjects were later asked to recall the repeated word - a surprise request - Paivio and Csapo found that subjects in the image condition performed far better than subjects in the pronounce condition. This was argued to demonstrate a superiority of imagery (nonverbal) codes in recall. It was also noted that where the subjects alternated between imagery and pronunciation (encouraging dual-coding), the target word was recalled better than if it had been presented once in only either the image or pronunciation condition, again suggesting the additive nature of the systems under certain conditions.

Evidence has also been presented which demonstrates interference in the verbal and nonverbal systems. Segal and Fusella (1970) demonstrated that if a subject is asked to do a perceptual task, for example, whilst concurrently performing an imagery task, or to perform an auditory task whilst also forming auditory images (i.e., thinking of specific sentences, words or phrases whilst detecting target words) then interference will occur. If the concurrent task relates to the opposite system, however, (e.g., a verbal task and concurrent pictoral imagery) the interference produced is not significant. Findings such as these seem to suggest that perception and imagery, for example, involve the same cognitive routes - an hypothesis that is proposed by the Paivio dual-coding theory. However, other researchers have demonstrated that the nonverbal system may be more complex than is apparent from the evidence presented thus far.

The studies reviewed above have concentrated upon specifically *visually imageable* tasks (such as forming a mental pictoral image of an object). However, there is evidence that purely *spatial* tasks will also interfere with imaging performance. For example, Baddeley and Liberman (1980) presented subjects with a task where they had to try and remember the layout of digits in a matrix. The location of the digits were presented aurally, but were either very easy to visualise (e.g., in the first square put a digit; in the next square to the right put a digit; in the next square down put a digit; and so-on) or difficult to visualise (e.g., the instructions were changed so that spatial terms right, left, up, down, were replaced by non-spatial terms such as good, strong, weak, bad - based on Brooks, 1967). Subjects were also presented with a concurrent task that was either specifically visual (judging brightness on a screen), or specifically spatial (tracking the location of a moving pendulum which emitted a certain sound when the subject was able to keep a flashlight trained on it - the subject being blindfolded so that the task could not involve visual components). Baddeley and Lieberman (1980) found that subjects were most disrupted in remembering the easily visualised matrix when concurrently performing the spatial tracking task and not the purely visual task. The same results were found if the concurrent task was both visual and spatial (e.g., a pursuit rotor task, where the subject visually tracks a moving light). Performance on the matrix that was difficult to visualise, and was thus arguably recalled via rote memory, was not affected. These results suggest that the nonverbal system proposed by the dual-coding theory incorporates visual imagery *and* spatial imagery - an aspect that was not fully explored in the basic theory.

Finally, some evidence has been presented supporting Paivio's suggestion that the right hemisphere of the brain may be specialised for processing imagery. Galin and Ornstein (1974) presented imagery tasks to subjects whilst recording their levels of brain-wave activity. Galin and Ornstein found that during imagery tasks, subjects demonstrated higher alpha-wave amplitude in the left hemisphere as opposed to the right. Alpha amplitude is suggestive of a relaxed state, or idle processing, thus the finding suggests that the right hemisphere is more active when performing imagery tasks. However, more recent research, especially in neuropsychological studies, has suggested that both hemispheres are involved to some degree in imagery processes. These, and other neuropsychological findings, will be reviewed shortly.

Paivio's dual-coding theory has been supported as a broad description of cognitive processes, with evidence that there is a distinction between verbal and nonverbal processes in the brain, and that there are relationships between the cognitive routes used for perception and imagery, across modalities (visual, auditory, etc.). It is also apparent that nonverbal processes are not simply segregated, and that there may be a close relationship between visual perception, spatial processing and mental imagery, for example. This visuo-spatial system has been proposed in particular by Baddeley (e.g., Baddeley, 1990, chapter 5), who argues that "....it can be fed either directly through perception, or indirectly, ...through the generation of a visual image....it seems likely that it either represents a multi-faceted system, with both visual and spatial dimensions, or possibly two separate systems." (Baddeley, 1990, pp.109).

Thus, the first model of imagery explored in this review - Paivio's dual-coding theory - enabled a basic, broad description of how imagery processes may relate to perceptual processes, and the way in which those processes may be divided in cognitive function. This provided a theoretical starting point from which specific experiments could be conducted.

The second model of imagery that will be explored is concerned less with general descriptions of cognitive processes, and more with the specific nature of mental images

- how they are represented, how they are formed, what the limitations are, and so-on. It is to this model that the review now turns.

5.1.ii: Kosslyn's Model of Imagery

Kosslyn (e.g., 1980; 1983; 1994) proposed a model of imagery that reflects many of the processes used in normal visual perception. That is, visual images are generated and maintained by utilising mechanisms that are involved in the top-down processing of visual perception.

The model suggested by Kosslyn is a computational one which incorporates several processes and cognitive structures, such as a spatial medium where the images are argued to be represented, image "files" which hold information and knowledge concerning the concepts to be imaged, and the related processes which draw the conceptual knowledge from these files and use it to represent the image in the spatial medium. The processes which Kosslyn proposes are many and complex, but include pattern activation, spatiotopic mapping, encoding of spatial relations, encoding of motion, shifting of attention, changing of shape, looking up related properties (e.g., categorical), identification of colours and textures, and associative memory (see Kosslyn, 1994, chapter 3). Each of these processes has been given an hypothesised location in the brain (e.g., posterior parietal lobes for spatiotopic mapping), but for simplicity this review will concentrate on the way the medium, processes and files work to generate and maintain mental images, rather than any hypothesised specific cognitive locations for such functions.

The Spatial Medium - This is a space with limited size and shape, a specific "grain" (like pixels on a television screen) which limits the amount of detail that can be imaged, clearest resolution of the image at the centre (the outer edges are fuzzier), and a limited image life-span (once an image has been generated in the medium it will begin to fade) (see e.g., Kosslyn and Shwartz, 1977). Kosslyn provided experimental evidence to support his claims about the nature of the spatial medium. For example, if the spatial medium is of limited size and shape - that is, it has boundaries outside of which an image will not be "seen" - then images should overflow the medium at a certain point. Kosslyn (1978) tested this. He instructed subjects to image an elephant in the distance, for example, and then to image walking towards the elephant until it filled their mental vision. At this point they had to estimate how far they were from the imaged elephant. Kosslyn (1978) found that the distance away when the imaged animal filled the subjects' mental vision was much greater for large animals, like the elephant, than for small animals such as a mouse. This difference was linear, and equated to a limited visual arc in the spatial medium, or "mind's eye". In another experiment Kosslyn demonstrated that when subjects are instructed to image two separate points, and to gradually image them moving closer to each other, the two points will eventually fuse (Finke and Kosslyn, 1980). This demonstrated that the nature of the images and the spatial medium have a specific resolution, as well as a specific area.

In addition, Kosslyn (1975) asked subjects to image an animal (e.g., a duck) and to see if they could "see" a small feature on that animal (e.g., the beak). The animal was imaged in a pair with another animal, either one that was much larger (such as an elephant) or one that was much smaller (such as a fly). Kosslyn (1975) found that subjects took longer to "see" the target feature if the target animal was imaged next to a much larger animal, rather than a smaller one. Kosslyn argued that this was both because the spatial medium preserved the spatial relationship of the animals as in perception - keeping the duck smaller in size relative to the elephant, for example - and because the grain of the spatial medium could thus not clearly represent the small target beak. When the duck was imaged next to a fly it was larger relative to the fly, and so the grain of the medium could clearly represent the duck's beak.

Experiments such as these have supported Kosslyn's claims that the medium where images are represented is spatial, of limited extent, and of particular focus. There is some debate as to whether this is the only explanation, however, and this will be explored later in the outline of the analogue versus propositional debate.

Image Files - These files are stored in associative memory, for example, and in conceptual knowledge bases. Thus files can store information image representations of all or of part of the object to be imaged, in sketchy outline form of the concept, or as a photo-like memory representation. Files also hold information relating to different parts of the object to be imaged (e.g., the wings of a duck, and how they attach to a duck's body), information about relative sizes, variations in shape and colour - superordinate and subordinate information, and so-on. Thus it is possible, according to

Kosslyn (1994, chapter 9) not only to image objects from associative memory, but also to image novel objects and transformations, and novel patterns. All of the required information would be stored in the various interconnected image files. It should be noted here that whilst experiments exploring mental imagery transformations by rotation, for example, and imagery of "novel" objects (that is, imaging two empirical objects combined in a unique way to form the image of another empirical object) have been conducted (and will be reported shortly), as yet Kosslyn has no experimental evidence exploring mental imagery of "novel" objects that are novel in the sense that they are *fictional* (established through correspondence with Stephen Kosslyn). This aspect of novel imagery is perhaps most closely related to imagination, pretense and creativity, and thus of extreme relevance to this thesis.

Image Processes - When one generates an image, several processes are utilised in order to take the relevant information from the image files and produce a mental image in the spatial medium. Examples of these processes have been presented earlier, but they could involve, for example, selecting a file depicting the sketchy outline of the object to be imaged, then adding the related components (e.g., wings, beak) and related colours, and so-on. The processes can also manipulate and alter the image through rotation, scanning, etc. (See e.g., Kosslyn, 1983, chapter 7). Although Kosslyn has hypothesised the functions and performance of image files and image processes, these are not specifically supported through experimental evidence, since they are modelling hypothesised cognitive functions and thus do not present easily testable propositions. However, Kosslyn's theory as a whole has much experimental evidence to support it, and this will be outlined shortly, along with other neuropsychological studies on imagery.

5.2: Mental Imagery - The Propositional versus Analogue Debate

The debate over the precise nature of mental images has been a forefront issue in cognitive psychology for many years. Ever since the well-reported study carried out by Galton in 1883, (see e.g., Eysenck and Keane, 1990, pp.207; Mandler and Mandler, 1964) where he presented fellow academics with a questionnaire asking them to imagine what they had eaten for breakfast that day and discovered that a high proportion claimed to have no experience of conscious mental imagery, psychologists and philosophers have debated whether mental images are like "pictures" or are simply abstract sentence-like propositions, or even whether they exist at all. The former position, that mental images reflect vision - that is, they are depictive and analogous to perception in nature - has strong support from such researchers as Shepard and Meltzer (e.g., 1971) and Kosslyn (e.g., 1980; 1994) whose model of imagery was reviewed earlier. The alternative position, which will be explored here first, is that mental images are not image-like at all, but rather are side-effects of abstract cognitive processes that underlie brain function and which are not specifically related to pictures, or to language, but are a "..universal, amodal, mentalese.." (Eysenck and Keane, 1990, pp.220). The main proponent of this propositional argument is Zenon Pylysyhn.

5.2.i: Mental Representations as Propositions

Pylyshyn (e.g., 1973: 1979: 1981; 1984) argued that to claim that mental images are picture-like by nature is to assume that there is a physical "mind's eye" which can "see" these pictures. (This should not be confused with Kosslyn's use of the term "mind's eye", described earlier. Kosslyn uses the phrase metaphorically to imply the mechanism by which the brain is aware of and examines mental images. Pylyshyn is arguing in a literal sense, that to "see" mental images the brain would need an internal "eye"). He claimed that there is no evidence to support such an assumption, and mental imagery can rather be explained as accompanying other underlying cognitive processes - processes which, because they need to allow relations between different codes (such as non-verbal and verbal - see the review of Paivio's dual-coding theory reported earlier), need to be propositional by nature.

The concept of propositional representation is a complicated one to try and explain. In simple terms, the hypothesis is that all cognitive processes can be conducted by utilisation of an abstract code - neither pictoral nor linguistic in nature - which incorporates information about relevant concepts and empirical knowledge. Propositional theorists present examples by using a logical system known as predicate calculus, although it should be noted that this is not meant to suggest that propositions are linguistic. For example, to describe a scene where a book is on a desk, a propositional representation will express the conceptual relationships involved without utilising pictoral or linguistic processes. This example could be written as: ON (BOOK, TABLE), where the predicate ON links the concepts BOOK and TABLE, all of these in the example being *mental concepts* and not words (Eysenck and Keane, 1990, pp.220-221).

Pylyshyn (e.g., 1981) claimed that studies which reported evidence that subjects were utilising visual imagery to perform tasks such as mental rotation, for example, (e.g., Shepard and Meltzer, 1971) cannot unequivocally claim the processes involved are depictive by nature. Rather, he suggested that subjects behave as they do not because they are experiencing picture-like images, but because they employ their tacit knowledge of how visual perception works and thus *simulate* vision during these tasks. This can apply to all claims of experience of "pictures in the head" - they are not depictive, pictoral images at all, but are the side-effects of someone who is using their tacit knowledge of the visual system to simulate perception, even though the mental processes themselves are by nature propositional.

Pylyshyn's hypotheses are generally founded upon complex philosophical arguments, although there is some experimental support for his claims. The empirical evidence comes in the main from studies he performed to counterbalance the work done by Kosslyn and colleagues (which will be expanded upon shortly), and where they demonstrated evidence that mental imagery involved analogue representations based upon the visual system. In a series of experiments, Pylyshyn (1984) demonstrated, for example, that if subjects were asked to image walking from one point to another, or running from that same point to the other, the time they would estimate taking varied. He claimed this supported the argument that subjects simply simulate real perception - that is, they mentally represent what it would be like to *really do* what they are asked to image - and that they are not mentally "looking at" (or "scanning") a visual mental image at all.

A similar study by Intons-Peterson and Roskos-Ewoldsen (1988) found that subjects would estimate taking longer to complete an imaged journey, walking a familiar route, if they were told to imagine they were carrying a cannonball than if they imagined they were carrying a balloon.

Other experiments and claims by propositional theorists have been supplied as arguments against the analogue hypothesis of imagery, but since these are often directly related to specific analogue experiments they will be included in the following review of analogue theory as criticisms, where relevant.

Thus, in summary, the propositional argument states that mental images are not images, but are effects brought about by abstract mental processes, and the related attempts by individuals to simulate reality according to their tacit knowledge.

5.2.ii: Mental Representations as Analogous to Perception

The analogue side of the debate on mental imagery suggests that visual mental images are founded upon certain aspects of the brain processes which are involved in normal visual perception. This ties in with the dual-coding hypothesis proposed by Paivio (e.g., 1969; 1986). In this way, the analogue hypothesis argues that mental images are depictive by nature - that is, they form a direct *depiction* of what one is visualising. This depiction is similar to a picture in it's representation, but it is not necessarily pictoral - it does not require eyes to see it, for example. In other words, whereas the propositional explanation suggests that there is nothing to "visualise" mentally in the formation of mental images, and mental imagery involves purely abstract thought processes, the analogue explanation suggests that visual mental imagery involves a specific depiction, perceived as visual because of its connection with the cognitive functions involved in visual perception. For example, Neisser (1972, pp.245) stated that "..a subject is imaging whenever he employs some of the same cognitive processes that he would use in perceiving, but when the stimulus input that would normally give rise to such perception is absent."

Some of the most widely reported experiments as evidence for the analogue nature of mental images are those involving mental rotation (e.g., Shepard and Meltzer, 1971; Cooper and Shepard, 1973; Cooper and Podgorny, 1976). Shepard and Meltzer (1971) presented subjects with two-dimensional pictures of three-dimensional shapes. The shapes came in pairs, and the subjects had to decide whether the shapes they saw were identical to each other. Some of the shapes were presented as mirror-images. Shepard and Meltzer not only found that it took longer for a subject to decide if the shapes were identical when they were mirror-images, but also that the response time increased linearly according to the degree of angular relationship between the two shapes. Shepard and Meltzer concluded that this was due to the subjects having to rotate the images in their mind - mental rotation - until they could confirm they were identical, and that it took longer to rotate the image when it was at a greater angle of difference to its pair shape. This supported the hypothesis that mental images are analogous to perception, and depictive by nature.

Similarly, Cooper and Shepard (1973) presented subjects with representations of pairs of letters and numbers, which were either identical, or had one of the pair as a mirror-image, and which were rotated through various degrees. Subjects had to decide whether or not the second representation was a mirror-image of the first. As with the findings by Shepard and Meltzer (1971), Cooper and Shepard (1973) found that subjects took longer to make a decision the farther from upright the angle of rotation was. Once again they concluded that this effect was due to the subjects having to rotate the image further before confirming its orientation, and that this suggested a depictive nature of mental images.

However, as mentioned earlier, it is possible to argue that decision times were increased in these examples not because subjects were actually attempting to rotate some depictive mental image, but because the abstract calculations are more complex when the test items are rotated further, or because the subject is applying tacit knowledge of how long it takes to rotate an object and is simulating that process. Unfortunately, the second of these explanations put forward by propositional theorists (e.g. Pylyshyn, 1981) supposes, for example, that there are governed speeds at which things rotate, and which can then be simulated - a somewhat unlikely explanation. However, Hinton and Parsons (1981) demonstrated that people do not always perform accurately on tasks involving mental rotation, suggesting that mental images are not accurate depictions of perception, and thus cannot be analogous. They asked subjects to imagine a cube on a shelf at eye-level. The subjects then had to imagine taking hold of the bottom left corner at the front of the cube with their left hand, and the top right back corner with their right hand, and then rotating anticlockwise until their right hand was directly above their left. Subjects were then asked to describe the locations of the corners they were not holding. Hinton and Parsons found the majority of subjects stated that the remaining visible corners formed a square shape, whereas in reality the corners would appear in a zig-zag formation. This could be evidence of a failed simulation, since an analogue representation should arguably reproduce perception in an accurate way. The subjects perhaps failed because the abstract propositions required for such a task were too complex. Evidence such as this, along with the arguments raised by Pylyshyn (e.g., 1981), require analogue theorists to present more evidence in their favour.

In a series of experiments, Stephen Kosslyn explored peoples ability and performance on tasks of mental scanning. For example, Kosslyn, Ball, and Reiser (1978) showed subjects a map of a fictional area - somewhat like a treasure-map - and asked them to memorise the map and the locations it showed. When the subjects could draw the map from memory, they were asked to imagine the map and concentrate on a certain specified location (one of the fictional towns marked, for example). They were then asked to concentrate on a second location on the map, to imagine a flying black dot moving between the two locations, and to report when the dot had reached the second location. Kosslyn et al. (1978) found that the time taken to scan between the two imaged locations changed in a linear fashion according to the actual distance apart of the locations on the map. This was presented as evidence to support the hypothesis that mental images are both analogous and depictive. Although the model of imagery postulated by Kosslyn, and described earlier, apparently incorporates aspects of propositional-type processes in the brain, these are encompassed within Kosslyn's overall argument that imagery utilises parts of the brain that are involved in perception, and is ultimately analogous to perception, with recognisable depictive mental images.

A similar experiment was reported by Baum and Jonides (1979), who asked subjects to mentally image a familiar location and then scan between two points in the imaged area. Once again, the reported time to scan between points was longer if the actual location was further away. However, as has been described, Pylyshyn (1984) provided alternative evidence to suggest that mental scanning is equally as related to simulation of vision (i.e., behaving as if you are really seeing, even though the visual system is not involved) as it is to an actual analogical visual process (i.e., involving actual parts of the cognitive visual system).

Since the early experiments involving mental rotation and mental scanning seem to be explicable by both the analogue and the propositional hypotheses of mental imagery, Kosslyn presented other experiments which were designed to explore more specifically the nature of mental images, (see the earlier section exploring his model of imagery). For example, Kosslyn (e.g., 1975; 1976) asked subjects to imagine a familiar object or animal - such as a horse - and then answer questions about certain features of that animal or object (for example, whether the tail was higher than the knees). He found that when the target object was imagined next to something much smaller (e.g., a fly) the subject's responses were quicker than if it was imagined next to something much larger (e.g., a dinosaur). Kosslyn argued that this was due to the subject having to "zoom in" on the target object in the latter case, because the other imagined object was filling so much of the mental visual field that the target was relatively small and the subject had to close in to see it clearly, and thus answer the question. He argued that this suggests not only a depictive mental image which can be "looked at", but also that mental images take up a specified space in the "mind's eye" (see the earlier review of Kosslyn's model of imagery).

Kosslyn (1978) provided further evidence of the specific size and angle of the mind's eye. He asked subjects to imagine an object, and then to imagine walking towards that object until it completely filled their "vision". They then had to report how close they were to the imagined object. When subjects imagined small objects (for example, a mouse) they reported them as being much closer than when the imagined object was large (for example, an elephant). Kosslyn argued that this demonstrated a limited visual-image arc and limited spatial area to the mind's eye. However, propositional theorists still argue that to imagine relative sizes and to answer questions on aspects of imaged objects does not necessarily require a visual image to be formed (e.g., Richardson, 1983). Subjects could perform in the same way if they were simply applying empirical and conceptual knowledge to the task.

It appears, then, that such experiments are unable to provide definitive evidence to support either the propositional hypothesis of mental imagery, or the analogue hypothesis. However, recent neuropsychological evidence from patients with brain damage, and from normal subjects, has added much to the debate.

5.3: Neuropsychological Evidence of the Nature of Mental Images

It is through neuropsychological studies in the last decade that research into mental imagery, and knowledge about the cognitive functions involved, has advanced. These studies have included psychophysiological studies of the normal brain, as well as neuropsychological studies of patients who have suffered (or were born with) brain damage.

5.3.i: The Neuropsychology of Imagery - Studies with the Normal Brain.

Cerebral Blood Flow - One way of examining cognitive functioning is to monitor the rate of blood flow to certain areas of the brain during experimental tasks. The greater the amount of blood flow to an area, the greater the likelihood of that area's involvement in the task being performed. Roland and Friberg (1985) presented normal subjects with three tasks: (i) counting backwards in threes from 50; (ii) a verbal task where subjects had to think of a jingle and delete the alternate words; and (iii) an imagery task that involved imaging a familiar scene or route, and walking through it taking alternate left and right turns. Roland and Friberg found that the specific visual imagery task led to a significant increase in blood flow to the occipital lobes of the brain, as well as the posterior superior parietal and posterior inferior temporal areas.

Goldenberg, Podreka, Steiner, and Willmes (1987) asked subjects to memorise sets of words, some concrete and some abstract. The subjects were divided into two groups, one of which was specifically instructed to use imagery to help memorise the words. Goldenberg et al. found that blood flow patterns suggested an association between the occipital and inferior temporal lobes during imagery.

In a later study, Goldenberg, Podreka, Steiner, Franzen, and Deecke (1991) examined blood flow in normal subjects who were instructed to form either visual or acoustic mental images when presented with names of objects. Findings suggested increased blood flow to the left inferior occipital regions with both forms of imagery, but not with a non-imagery control group. However, Goldenberg et al. discovered that all imagery subjects had experienced visual images, even though some were instructed to only form acoustic images. Goldenberg et al. thus suggested that the areas which registered increased blood flow were important for modality-specific visual imagery. It is also interesting to note, however, that the spontaneous nature of the visual images being formed in the acoustic imagery condition could suggest that visual imagery is an automatic part of normal memory processes. Certainly, imagery has been shown to be extremely useful in the specific learning of mnemonic techniques (e.g., Yates, 1966; Sweeney and Bellezza, 1982; McEvoy and Moon, 1988).

Electrical Activity in the Brain - Studies have also been conducted which examine Event Related Potentials (E.R.P.'s) in the brain, in response to certain tasks. An E.R.P. is an electrical activity response in the brain which occurs as a direct result of a specific stimulus. E.R.P.'s can change both in location, and in polarity (positive or negative), thus demonstrating how the brain responds differently to varying stimuli. For example, Farah, Peronnet, Weisberg, and Perrin (1988) visually presented subjects with words, in two conditions. Subjects either had to read the words, or had to both read the word and mentally image what the word referred to. Farah et al. found that in the imagery condition E.R.P.'s in the occipital lobes showed a significant and localised increase in positivity, demonstrating increased occipital activity. Farah et al. also presented subjects with a control task where they had to detect misspelt words in a reading only condition. This was to test whether increased activity could have been due simply to increased task difficulty or effort. They found that this more effortful visual reading task did not produce the E.R.P. increase that was exhibited with imagery, suggesting that the increase was indeed specifically connected to the imagery component of the task.

A further psychophysiological method of exploring brain function during tasks involves the examination of electrical activity in the brain using E.E.G.. E.E.G. studies explore alpha rhythms in the brain. As has been mentioned earlier, alpha rhythms indicate a resting or "idling" level of activity, and thus reduced alpha rhythm levels demonstrate increased cognitive activity. Davidson and Schwartz (1977) measured alpha rhythms in the occipital and parietal areas of the brain during tasks involving visual imagery (imaging a flashing light) and tactile imagery (imaging a tap on the arm). They found that whilst overall alpha rhythm activity was no different between the two conditions, there was greater alpha rhythm suppression in the occipital area during visual imagery, and in the parietal area during tactile imagery. Other studies have also demonstrated alpha rhythm suppression in the occipital lobes during visual imagery (e.g., Brown, 1966; Slatter, 1960).

The common finding with all of the reported psychophysiological studies of normal brain activity during visual imagery tasks, whether recorded via E.E.G., of E.R.P.'s, or of blood flow, is that the area that is most active during visual imagery is the occipital area, with activity also sometimes occuring in posterior parietal and posterior temporal lobes (e.g., Roland and Friberg, 1985). The occipital lobes have been demonstrated to be the main area involved in visual perception - that is, in actually seeing objects in the external world - and the area where visual processing begins. The later stages of visual processing involve the posterior parietal and posterior temporal lobes (see e.g., Bruce and Green, 1989, for an overview). Thus, findings such as those described here have provided evidence that visual imagery does indeed involve the areas of the brain that are concerned with visual perception, supporting both Paivio (e.g., 1971) and analogue theorists such as Shepard and Meltzer (e.g., 1971) and Kosslyn (e.g., 1994).

However, the propositional theorist could argue that the visual areas of the brain are being activated because the subject is simulating visual perception, and therefore is creating activation in the parts of the brain that would normally be involved if he or she were really seeing something. Although this may appear unlikely, as it implies that the average man on the street both knows which parts of the brain are involved in visual perception, and can consciously control those areas (e.g., Farah, 1988, pp.314), one cannot ignore the possibility. Simulation may automatically trigger activation in the parts of the cortex that are involved in the real thing, without needing conscious effort. However, studies of individuals who have suffered brain damage have helped lend support to the analogue theorists, at the expense of the propositional hypothesis of mental imagery.

5.3.ii: Neuropsychology of Imagery - Brain Damage Studies.

Studies of brain damage have enabled visual imagery and perception to be explored quite comprehensively, including studies of damage to the occipital and parietal parts of the visual system, as well as specific aspects of perception such as the perception of colour. Neuropsychological studies of imagery have also suggested a dissociation between object processing and space processing within the visual system.

Damage to the Visual System: Parietal Lobe Damage - Bisiach and Luzzatti (1978) presented a study where they examined performance by patients with visual neglect of the left half of the visual field. Visual neglect is mainly associated with damage to the right parietal lobe of the brain, and is demonstrated by an inability to detect stimuli presented in the left half of the visual field. Thus, patients with this disorder are often reported as thinking they have finished a meal when in fact there is still food on the left side of the plate, or shaving only the right side of their face in the morning (see e.g., Springer and Deutsch, 1989; Heilman, Watson, and Valenstein, 1985). Typically, patients with visual neglect are *not aware* of their deficit. For this reason, the condition of visual neglect is useful for exploring the validity of the propositional theorists simulation argument. If, as is argued, imagery tasks are performed by simulating visual perception according to one's tacit knowledge of how perception operates, then patients who have suffered right parietal lobe damage sometime after they have developed a normal visual system should perform normally on imagery tasks. If, however, the imagery system involves the same cognitive processes as the visual perceptual system, then the neglect that is apparent in the patients perception should also be apparent in their imagery performance.

Bisiach and Luzzatti (1978) asked two patients with left visual field neglect to image looking at a scene that they both were very familiar with (and had been familiar with *before* their brain damage) from a certain perspective. The subjects were then asked to describe what they could "see". Both patients reportedly failed to refer to any objects or landmarks that would have been on the left of their visual field. When they were then asked to repeat the task, but this time imaging the scene from the other direction, they both referred to the objects that they had previously failed to report and omitted the landmarks which they had previously described.

In a later study with a group of neglect patients, Bisiach, Luzzatti, and Perani (1979) presented the subjects, and controls with brain damage but not visual neglect, with a series of pairs of abstract shapes. The pairs were presented to the central visual field, and moved across from right to left so that the neglect patients were able to see all of the stimuli as they were presented. When the subjects were later asked to say which pairs were matching pairs, thus arguably requiring them to form visual memory images of the stimuli in order to make the decision, the neglect patients made far more errors when the stimuli differed on the left side only, incorrectly describing pairs as matching when in fact they were different. These two studies by Bisiach et al. suggest that imagery is a related function of the visual system, and is not simply a simulation of perception based on tacit knowledge and propositional in nature.

Damage to the Visual System: Occipital Lobe Damage - In a study by Farah, Soso, and Dasheiff (1992) the claims made by Kosslyn (e.g., 1994, see earlier review of his theory) that visual imagery is represented via a medium that has a limited extent, were tested. As was reported earlier in the chapter, psychophysiological studies of the brain have supported the hypothesis that visual imagery is related to visual perception processes, and triggers activation in the occipital lobes. Farah et al. (1992) tested the performance of a patient who was given a lobectomy of the occipital lobes as treatment for epilepsy. Before the operation she demonstrated normal vision and visual imagery performance in tasks where she had to image an object and estimate its size and its distance from her when it filled her "mind's eye" (see e.g., Kosslyn, 1978). Using the estimated sizes and distances provided by the patient for a variety of objects, Farah et al. were able to estimate the visual angle of her "mind's eye" (mean angles: 48.3 degrees horizontal, and 40.2 degrees vertical). After the operation, the patient was again asked to image a variety of objects and estimate their size and distance from her.

Results suggested that the visual angle of her "mind's eye" - or imagery representational medium - was significantly reduced, but only in the horizontal and not the vertical plane (mean post-operation angles: 29.5 degrees horizontal, 38.3 degrees vertical). Farah et al. also stated that the subject was unaware that they were testing her imagery abilities, and that she was confident when asked that she had been using mental imagery and had not been "working out" the answers from a tacit knowledge of how close one has to be to objects to see them clearly. Thus, the results suggest that when the areas of the brain concerned with visual processing (particularly the occipital lobes) are damaged, or excised through surgery, this results in changes to the imagery representational medium. The findings therefore support Kosslyn's hypothesis that "..images occur in a spatially mapped representational medium." (Farah et al., 1992, pp.245).

Colour Perception and Imagery - Further studies of concurrent visual perception deficits and visual imagery deficits have been reported for patients suffering from deficits in colour perception. Sacks and Wasserman (1987) described patients who had acquired brain damage which led to colour blindness. These patients were able both to draw and to describe objects from memory (a task that arguably requires imagery), but were unable to describe the colours of the imaged objects.

Beauvois and Saillant (1985) reported a subject who had had a stroke, resulting in a disconnection of her language and visual areas. When she was asked to describe the colour of something via a method that could rely on linguistic knowledge (e.g., "You have learnt what colour snow is. What do people say when they are asked what colour snow is?"), she was able to answer correctly. However, when she had to respond through using mental imagery (e.g., "Imagine a beautiful snowy landscape. What colour is the snow?"), she was unable to answer correctly. Beauvios and Saillant (1985) suggest that this was because of the disconnection between the visual and language functions, and is a result that would be expected if imagery and vision involve the same cognitive areas.

In an earlier study, DeRenzi and Spinnler (1967) presented a variety of brain-damaged patients with a task involving colour perception (sorting coloured squares of paper in to pairings of the same colour) and a task involving colour imagery (describing the colours of imaged objects). As with the study by Sacks and Wasserman (1987) they found a correlation between colour-perception deficits and a lack of colour imagery. Once again, these experiments suggest a link between the cerebral structures involved in visual perception, and those involved in visual imagery, supporting the analogue theory.

However, neuropsychological studies have also demonstrated that there is a dissociation between visual imagery and spatial imagery, raising again the issue of an hypothesised visuo-spatial system (e.g., Baddeley, 1990).

Visuoperceptual and Visuospatial Imagery: Evidence for two systems - One area of research that has lent support to the possibility of spatial imagery and perceptual imagery involving different processes is that of imagery in blind subjects. Several studies have reported that blind subjects are able to internally represent , or mentally image, the spatial properties of objects when they touch them, or perform tasks of mental rotation (e.g., Jonides, Kahn, and Rozin, 1975; Carpenter and Eisenberg, 1978; Marmor and Zaback, 1976). This finding was specifically tested by Hollins (1985) who presented blind subjects with two imagery tasks. One task involved pictoral imagery, where the subjects had to imagine a "checkerboard" in which the black squares were specified by the experimenter and formed a two-dimensional picture of an object if imaged correctly. (The checkerboard grid was 8 x 8, numbered 1 to 8 on the top row, 9 to 16 on the second row, and so-on up to 64. The black squares were thus denoted by numbers). The second task involved spatial imagery, where the subjects had to imagine a three-dimensional object. In this case subjects were told they would be given numbers representing solid cubes in a 4 x 4 x 4, three-dimensional matrix. This matrix was divided into four "slabs" (4 cubes wide, 4 cubes high, and 1 cube deep), with numbers for the solid cubes in the front slab being given first. In this way, the subjects could build up a three-dimensional image of an object, but could not guess the object from the front "slab" alone (as this would be similar to pictoral imagery).

Hollins (1985) presented these tasks to blind subjects who had been blind for differing lengths of time. Thus, one subject was blinded only six months prior to the experiment, whilst others were blind from birth, with a range of subjects falling between these two extremes. Many of the subjects were thus peripherally blind as opposed to cortically blind (i.e., suffered damage to the eyes rather than to the visual cortex in the brain). Sighted control subjects were also used, and instructed to keep their eyes closed whilst participating in the experiment.

Hollins found that subjects who had been blind for most or all of their life scored higher on the stereoplastic (spatial) imagery task and lower on the pictoral imagery task. The reverse was true for subjects who had been blind for only a short while. These performance ratios "varied systematically as a function of visual history" (Hollins, 1985, pp.565). The results presented by Hollins thus demonstrate that imagery can be either spatial or pictoral, or both, at least in the blind population.

The fact that blind subjects in Hollins' experiment could utilise pictoral imagery offers support to the propositional theorists argument that imagery is a simulative process. The subjects who had only been blind for a short while may have succeeded in the pictoral imagery task by simulating what they remember experiencing when they were sighted. The congenitally blind subjects, on the other hand, appeared to image by spatial and/or tactile imagery, possibly simulating their experience of the world and thus not experiencing pictoral imagery. However, the recently blinded subjects were mostly not blinded through brain damage in Hollins' study, and as reviewed earlier subjects with visual deficits due to brain damage also appear to suffer related imagery deficits. Thus, even though it may initially be possible to argue for simulation in subjects with a normal cortical visual system, subjects with damage to that cortical system demonstrate that this is not the case. Imagery appears intrinsically linked to the cortical visual system through a sharing of processes rather than simulation of tacit knowledge (see e.g., Farah, 1988, pp.315).

Studies with blind subjects and imagery support the possibility of spatial as well as pictoral imagery, but studies with sighted individuals also need to be presented since the workings of a blind person's brain may not mirror those of the sighted. Several researchers have presented evidence of spatial processing differing from object processing (e.g., Farah, Hammond, Levine, and Calvanio, 1988; Ungerleider and Mishkin, 1982; Levine, Warach, and Farah, 1985), and Kosslyn (e.g., 1987; Kosslyn, Flynn, Amsterdam, and Wang, 1990) has proposed a hypothesis of imagery generation incorporating this idea.

Levine, Warach, and Farah (1985) presented a study of imagery which highlighted the dissociation between visual-object perception and imagery, and visuo-spatial perception and imagery. Levine et al. (1985) examined two patients with differing brain damage. One of the patients demonstrated prosopagnosia, a disorder where the subject finds it hard to identify objects, often faces, animals, and specific places in particular. This patient not only had difficulty identifying pictures of faces and animals with which he was presented, but also showed a related imagery deficit, as measured by asking for descriptions of objects, and drawings. Neither his perceptual nor imaginal spatial awareness was affected, as measured by pointing to objects in space, drawing route maps from memory, and describing directions, for example.

The second patient suffered from visual disorientation. He demonstrated deficits in direction sense, locating objects in space, body perception, and other perceptual spatial abilities. This was accompanied by a mirrored imagery deficit - he could not describe familiar routes, or point to objects in a familiar room whilst blindfolded. On the other hand, he showed no deficits for object perception or imagery, and was able to identify faces, animals and so-on from pictures, as well as draw or describe objects accurately.

Levine et al. (1985) also reported similar cases from the literature, stating that of 28 cases of prosopagnosia reported 14 also reported related imagery deficits, whilst the others either did not test imagery, or relied on limited tests and/or patient introspection; and of 26 cases of visual disorientation 12 were tested for imagery deficits, with 9 reporting spatial imagery deficits (Levine et al., 1985, pp.1015). The authors conclude that there is "..a parallelism between abnormalities of perception and abnormalities of imagery....This parallelism suggests a relationship between the neural structures involved in perception and imagery...a portion of the pathway involved in the perceptual act coincides with a portion of the pathway involved when the act is only imagined. These congruent areas have distinct sites for different aspects of visual perception-imagery..." (Levine et al., 1985, pp.1017). Following their reviews and their own studies, Levine et al. suggest that visual disorientation and spatial imagery deficits result from parieto-occipital damage, whereas object and colour perception and imagery deficits result from temporo-occipital damage.

Farah, Hammond, Levine, and Calvanio (1988) provided further support for this hypothesis, presenting evidence from a single case study where a patient had suffered specific damage to the temporal and occipital lobes, but no damage to the parietal lobes. The subject showed deficits in recognising faces, animals, plants, and other complex objects, along with a related imagery deficit - he could not describe common animals, or say whether a rabbit was larger or smaller than a horse, for example. However, when presented with a series of tests requiring spatial processing - both perceptual and imaginal (e.g., mental scanning tasks, mental rotation tasks, locating points on a map or in a room, etc.) - the subject performed normally.

Kosslyn (e.g., 1987; Kosslyn et al., 1990) suggested that the pathways in the brain involved in imagery and perception, and which lead to the dissociations noted in the literature, represent two cortical visual systems. The dorsal pathway stretches from the occipital lobes to the parietal lobes. This is the system involved in analysing spatial properties, such as location, size and orientation. The ventral pathway extends from the occipital lobes through the inferotemporal area of the brain, and is the system involved in the analysis of object properties, such as shape and colour. Kosslyn suggests that these pathways cover both the left and right hemispheres of the brain. This suggestion is notably different to the right-hemisphere hypothesis of imagery that Paivio, for example, proposed (e.g., 1971). Kosslyn based his hypothesis on the variety of neuropsychological evidence available demonstrating imagery utilising the bilateral visual cortex. Although the functions of both hemispheres in mental imagery are generally accepted at present, some researchers have argued that since most neuropsychological research has been based on studies of patients with brain damage, care should be taken when generalising to the normal population (e.g., Sergent, 1990).

These postulated visual systems were integrated with Kosslyn's (e.g., 1983; 1994) model of imagery to provide an hypothesis on how they could relate to image generation. Thus, Kosslyn (1987) suggested that the dorsal system may recognise and activate stored representations of parts of objects in different orientations, locations, and positions, whilst the ventral system may activate stored representations of shapes of whole or part objects, for example. This relates to the hypothesised image files and processes of his computational model of imagery, and presents an overall hypothesis on the neuropsychology of image generation.

Whether the hypothesis proposed by Kosslyn (e.g., 1987; 1994) is an accurate description of imagery processes in the normal brain is as yet unknown. However, the large amount of evidence provided from neuropsychological studies strongly supports the analogue theory of imagery, with experiments consistently finding a close relationship between the visual perceptual processes in the brain and related imagery processes. Evidence suggests that elements of Paivio's (e.g., 1971; 1986) dual-coding theory, describing nonverbal processing, and Baddeley's (e.g., 1990) visuo-spatial sketchpad can both be supported, as well as the more specific hypotheses concerning the nature of mental images proposed by Kosslyn (e.g., 1983; 1994), although the complexity of brain functioning is such that each of these is somewhat oversimplified. Nevertheless, it is clear that veridical mental imagery is accepted as a scientific phenomenon which relates to visual perception processes, and is therefore analogous to vision and is depictive. As yet, such neuropsychological studies have not been conducted exploring *non-veridical* mental imagery, even though its existence is undoubtedly accepted (see e.g., Kosslyn, 1994). Finke, Pinker, and Farah (1989) have explored imagery performance by normal adults when instructed to image two veridical shapes (e.g., capital letters) and combine these in a novel way to form an image of another veridical shape. (For example, imagining a capital letter "J", and a capital letter "D" which is on its flat side resting on the top of the "J". This forms the novel image of an umbrella.) Finke et al.'s (1989) study therefore explored creation of novel images, but these images were still veridical. However, there are some studies exploring the psychology of *imagination* which include some non-veridical processes (e.g., pretense). It is to these that this review now turns.

5.4: Imagination - Evidence from Normal Development.

As was stated at the outset of this review chapter, the border dividing imagery and imagination is somewhat fuzzy. Whilst mental imagery as a veridical process that involves the visual cortex has been examined, with the conclusion that mental images are actual occurrences analogous to perception, imagination has been explored not in an attempt to discover its nature and location in the brain, but in regard to its effect on development, reasoning, creativity, and other cognitive functions. Thus, the methods used to explore mental imagery have been somewhat different to those employed to examine imagination. However, when one discusses an individual who is believed to have an active imagination, it is often readily assumed that that imagination is experienced in part as imagery. Conversely, it is often also assumed that for an individual to participate successfully in mental scanning or visual memory tasks, for example, he or she uses imagination. These similarities between mental imagery and imagination are due as much to the interchanging use of such terms - a practice that can lead to some confusion - as to the possibility that mental imagery and imagination really are closely related. In an attempt to clarify both the differences and the similarities between mental imagery and imagination, this review examines the two areas separately. Having presented a review of imagery literature, this will now be balanced by a review of imagination literature, and the postulated involvement of imagination in cognitive development, including pretense, reasoning, and creativity.

5.4.i: Imagination: Pretense and Simulation

Pretense is a behaviour that emerges in normal development between about 18 and 24 months of age, and is by its nature one expression of imagination. Children who pretend may interact with invisible objects or people, or feed building block "cakes" to dolly who is very hungry, or behave as if they were superheroes or pirates, and so-on. Pretense is very diverse, and universal among normally developing children. Several theories of pretense have been proposed over the years, from Piaget (e.g., 1962) who suggested that pretense was a form of symbolising, or of forming a symbolic mental image of an absent object in the presence of a perceptually similar object; to Vygotsky (e.g., 1962) who suggested that pretense develops as the child comes to understand first highly diverse interpersonal relationships, and then their own varying ways of relating to the world and others, thus enabling the development of varied abstract mental processes; to Fein (e.g., 1975) who proposed that pretense develops as children learn to draw analogies between objects and entities through a process of transformation (or selecting some features of a present situation or object, comparing these to similar objects and situations in memory, and drawing up analogies). Each of these hypotheses has been related to overall cognitive development in childhood, but in more recent years hypotheses have emerged which provide a more detailed and specific examination of the nature and role of pretense and imagination. It is these more recent works which will receive most attention in this review.

Leslie's Metarepresentation Hypothesis - One of the most detailed explorations of the role of pretense in cognitive development in recent years has come from Alan Leslie (e.g., 1987; 1994; see chapter 1). Leslie proposed that development of pretense in young children is a precursor to the development of a theory of mind, that is, to the development of an understanding that oneself and others have opaque mental states which govern behaviour, and which differ from person to person depending on ones knowledge (e.g., Premack and Woodruff, 1978). He claimed that "The metarepresentational theory reveals pretend play in a new light as a primitive manifestation of the ability to conceptualise mental states." (Leslie, 1987, pp.424). Thus, to Leslie, pretense is an important if not vital stage in cognitive development.

Leslie's (1987) theory of pretense shows evidence of incorporating mental imagery aspects, although this is not as specific as the concept of mental imagery employed by Kosslyn (e.g., 1994) or Farah (e.g., 1988), for example. Leslie (1987, pp.416-417) suggests that in order to pretend one must first be able to form an internal *primary representation*, which accurately represents objects and situations in the world as depicted by perception. This definition is arguably very similar to mental images as explored by neuropsychological experiments, with the exception that Leslie does not specify primary representations as imaginal. However, since neuropsychologists (e.g., Farah, 1988, pp.315) do not suggest that images are necessarily pictoral, for example, but are merely analogous mental depictions of perception, the similarities to Leslie's primary representations are clear.

Leslie (1987) proposes that for pretense to be possible the primary representation must be copied and separated from reality ("decoupled"), so that the copied representation can be transformed in ways that are not restricted by its veridical status. An example provided by Leslie (1987, pp.417) describing the process of pretending a banana is a telephone, is as follows: one forms a primary mental representation of a veridical object (e.g., a banana). From this primary representation is formed a decoupled representation (a "metarepresentation") - "this is a banana". Because this metarepresentation is now free from reality constraints, it can be manipulated in any way, and thus one can form a mental metarepresentation "this banana is a telephone". The decoupled metarepresentation has no relation to the real-world - it does not refer to real objects - because it is related only to a primary mental representation, but like the primary representation it too may be a mental image, although again this is not something that Leslie specifies.

Since studies of mental imagery have not explored non-veridical imagery, it is not possible to suggest conclusively whether aspects of mental imagery models could relate to Leslie's (1987; 1991; 1994) theories of metarepresentation and pretense. Kosslyn's (e.g., 1983; 1994) model of mental imagery included reference to image processes which can combine components in novel ways, thus forming novel images and patterns, and these processes might be similar to Leslie's decoupler. However, without experimental evidence specifically exploring mental image generation of non-veridical "pretend" images, any hypothesis of a similarity in the two theories is purely speculative.

Returning to Leslie's (1987) metarepresentation hypothesis of pretense, he goes on to suggest four different kinds of pretense in early development. *Immediate pretense* is where the individual forms a primary representation of the present situation, and proceeds with a pretend scenario based on knowledge relating to perceptually or functionally similar objects to the objects in the present scenario. For example, the child has an empty cup in front of her. She forms a primary representation of a cup, recalls related knowledge to do with function (such as containing), and proceeds with a pretend situation in which the empty cup is pretended to contain tea (Leslie, 1987, pp.420). In this case, the decoupled metarepresentation would be that of the cup full of tea.

Planned pretense occurs when one forms a primary representation based on knowledge or on memory, and then combines with this new knowledge that was not part of the original primary representation. This may entail the use of props rather than actual related objects. For example, one could form a primary representation of a party, and connect with this the concept of a birthday cake, which is then added to the pretend scenario using a building block as a prop (pp. 420-421). The decoupled representation is that of being at a birthday party with a birthday cake.

Remembered pretense again is based on the forming of a representation from memory, but in this case the representation is an already decoupled representation (e.g., "teddy is ill", pp.421). This pretense can take place either with or without the relevant object (e.g., teddy) being present, thus in some cases a prop may be used instead. Leslie argues that this kind of pretense may relate to children's play in which they model either their own or someone elses behaviour.

Finally, *understanding pretense in others*. Leslie (1987, pp.421) argues that this is where a primary representation is formed of what someone else is doing, to which a decoupled metarepresentation must be supplied that explains their actions. By supplying examples of differing situations in which pretense occurs, and the varying ways in which the child might employ metarepresentations, Leslie demonstrates the importance of metarepresentational thought from an early age.

In later work, Leslie (e.g., 1991; 1994; Leslie and Roth, 1993) adapted and updated his theory of pretense and its relation to theory of mind, to place greater emphasis on the role of attitude in understanding of metarepresentations (which Leslie now refers to as "M-Representations" (e.g., Leslie and Roth, 1993) partly because the term metarepresentation was being used in a slightly different context by Perner (e.g., 1991). Perner suggests that a metarepresentation is a representation of a representation. In this way, children engage in pretense by mentally representing both the real situation and an hypothetical, as-if, situation. The child then switches from the real to the hypothetical situation in order to pretend).

M-Representation is a representational system which is specialised for the understanding of agents and the attitudes which they hold towards propositions, and is an important component of the Theory of Mind Mechanism (or ToMM). These attitudes include not only pretense, but also beliefs, intentions, thoughts, and dreams, etc., and thus M-Representations are also necessary for developing a theory of mind. Leslie (e.g., 1994) argues that an agent's attitudes always relate to the truth of a proposition, thus, in pretense, one can understand someone talking to a banana by forming the M-Representation: Mary pretends (of) the banana (that it is true that) "it is a telephone". Her behaviour is then governed by the attitude which she holds. Thus, Leslie not only argues that to be able to pretend an individual must be able to form decoupled mental representations, but must also be able to relate those decoupled representations to hypothesised attitudes of themselves and others. In other words, it is not enough to be able to decouple and manipulate mental representations, since without an understanding of concurrent attitudes towards those representations it would be impossible to understand pretense. Mary could form a decoupled representation of a banana as a telephone, but if she does not hold an understanding of her attitude towards that banana (that she is pretending, rather than believing or wishing, for example) her behaviour could be at the least incomprehensible, and at most nonsensical.

Leslie's theory of M-Representation has not been without its opponents, especially from supporters of a more Vygotskyan approach that relates pretense to understanding of interpersonal relationships and affective relationships (e.g., Hobson, 1990; 1993; Wolf and Gardner, 1981). Hobson (e.g., 1993) argues that Leslie does not fully explain the way in which a child learns to appreciate others attitudes, and that his theory supposes an understanding of mental states and attitudes that is inferred from an assumed already present "theory" that others have attitudes and mental states, making Leslie's arguments somewhat circular. In Hobson's view, the early stages of development, from birth to around one and a half years of age, are fundamental to the child's awareness of other people as people, with varying attitudes, mental states, and so-on. These early years of development centre around affective relationships - perceiving feelings and emotions in ones self and others.

Hobson states (1993, pp. 209) "Affective co-ordination is critical for interpersonal engagement; interpersonal engagement is necessary for a child to register how persons differ from things in affording experiences of sharing, conflict, and so-on; such experience underpins the child's awareness of persons as having attitudes that co-ordinate with her own; and the interpersonal co-ordination of attitudes vis-à-vis the world is what effects the "decoupling" of the things or events in the world, from the descriptions under which those things or events may fall for different persons." Thus, Hobson attempts to explain a developing understanding of mental states that is based on a growing awareness of feelings and shared emotions.

Leslie (1994b) expanded on his theory, and confronted some of the arguments presented by Hobson, by presenting a cognitive developmental explanation of how the infant comes to understand other people as agents with attitudes, via an hypothesised cognitive mechanism relating to understanding of physical bodies (Theory of Body mechanism, or ToBy), which is succeeded by development of the Theory of Mind Mechanism (ToMM). In this later presentation of his theory, Leslie also divides ToMM into two stages, $ToMM_1$ and $ToMM_2$. Basically, Leslie suggests that from a young age (around 6 months old or possibly earlier) the infant begins to distinguish "agents" from inanimate objects, via their mechanical properties - they move as a result of internal or external forces. This is the level at which ToBy operates. Leslie (1994b) presents a full account of how ToBy might perform, analysing 3-D object movements in various ways, but this is not directly relevant here. Suffice to say that in ToBy, Leslie presented his potential missing link between lacking understanding of mental states and gaining that understanding. Once the infant has grasped the basic notion of what an "agent" is, through ToBy, $ToMM_1$ enables an understanding of the *actions* that agents have on other agents and on objects, and of what agents are perceiving. At a more advanced stage of development, $ToMM_2$ provides an understanding of the *attitudes* that agents hold. All of these mechanisms have an underlying factor guiding them, that of *intentionality*, and it is the understanding of intentions which Leslie sees as being fundamental not only to pretense, but to mental states and theory of mind as a whole.

As far as Leslie's latest adaptations of his theory apply, he has postulated a set of mechanisms that work together to enable full-blown understanding of mental states. There are still some potential criticisms in that his mechanisms work on the assumption that the infant is born with an innate understanding of intentionality, which may or may not be the case. However, as relates to pretense, his theory proposes pretense as incorporating the ability to mentally represent not only primary representations of the real world, but also decoupled representations which can be manipulated and changed - representations which may involve imagery - coupled with a necessary understanding of agent's intentions and attitudes.

Pretense and Simulation: The Flagging Theory - Simulation theory has been briefly reviewed in Chapter 1, as it relates to autism. Attention was drawn to the slight differences in approach from researchers favouring simulation theory, with Harris, for example, (e.g., Harris, 1994; Harris and Kavanaugh, 1993) adopting a simulation explanation that is less extreme than other simulation theorist approaches seem to be (e.g., Currie, 1995; Goldman, 1993). Simulation theory has a lot to say about pretense and imagination, and this review will continue now by exploring the argument put forward by Harris and Kavanaugh (1993) in support of the "flagging theory" of pretense.

Harris and Kavanaugh (1993) suggest that when a child engages in a pretend act, or watches and understands someone elses pretense, they do so by marking the specific episode as a *"pretend"* episode, and attaching "mental flags" or markers to the various props and situations which stipulate the status of those props and situations within the pretend episode. Once the props have been flagged appropriately, the child is able to utilise imagination to simulate the scenario that is being acted out, as if it were real. Harris (1994, pp.173) gives the example of a child watching her mother pretending to serve tea: ".. the child watches while an adult picks up an empty teapot, holds it above a cup, and tilts it. [The] child ...flags the teapot as containing make-believe tea; some of this tea is then poured into the cup so that the cup is also flagged as containing make-believe tea. Thus, a flagged statement regarding the cup might read: 'The cup contains (make-believe) tea'". Flags can also be updated at any time when relevant, and this process has been dubbed "Flag-editing" (Harris and Kavanaugh, 1993). This flag-editing occurs when the pretend status of a prop changes during a pretend episode. For example, at the beginning of an episode the child might decide to give a building block the flag "birthday cake", but at a later stage in the episode, that same prop may be used instead as a sponge. Provided the prop undergoes flag-editing, and is reassigned a new flag labelling it as now being a sponge during that pretend episode, this would not prove troublesome. In this way, a single prop may undergo several flag-editing procedures, and represent many different things within one episode. Harris and Kavanaugh (1993) demonstrated that young children have no difficulty in following these changes, and keeping tabs on the flagged status of props during an episode, even spontaneously changing the apparent flags when appropriate. Additionally, children are able to keep track of causal changes during pretend episodes. Thus, if a cup containing (make-believe) tea is poured over teddy, teddy will be "wet", and the cup will be "empty".

Harris (1994) suggests that since a flagging approach to pretense operates only upon a specific episode each time, there is no need to "decouple" the flagged representations from reality as Leslie argues, since they do not apply outside the specific pretend context. Thus, even when props undergo flag-editing, this does not entail the need for constant formation of new decoupled representations to relate to each newly flagged status. The child simply replaces the old flag with the new one. Via flag-editing, the pretend status of a prop can change swiftly back and forth, if necessary - an option that is not fully explored by Leslie (e.g., 1987). Leslie relates a decoupled representation specifically to a primary representation and an agent's attitude, and thus does not seem to allow for a quick and easy change in the status of the decoupled representation. However, it could be argued that since the decoupled representation is subject to manipulations which are unconstrained by reality, the problem could be resolved by simply suggesting that the decoupled mental representation *transforms* into the new decoupled representation.

In addition, Harris (1994) proposes that flagging relates only to pretense, unlike decoupling, which Leslie (e.g., 1987) claims is necessary for dealing with all kinds of mental states. Thus, according to Harris and Kavanaugh (1993) children can engage in pretend play without the need to know the mental state of anyone else involved. All that is necessary is to understand the way in which the situation has been flagged, and then behave as if it were reality. Thus "..the child's task is not to understand the mental state of the adult, but to figure out what that make-believe situation is and to act in concert." (Harris and Kavanaugh, 1993, pp.37). This is not to say that the child is in any danger of confusing the make-believe pretend situation with reality. Harris, Brown, Marriott, Whittall, and Harmer (1991), for example, demonstrated that young children understand that pretend objects cannot be touched or interacted with in the real world. Therefore, the flagging theory of pretense, whilst not concerned with providing a model of the development of pretense understanding from birth, or of relating pretense to theory of mind, provides a plausible alternative to Leslie's model which is governed by the notion that through imagination people can simulate a variety of pretend situations.

As with Leslie, the flagging theory proposed by Harris and Kavanaugh (1993) has not been free from criticism. Currie (e.g., 1994, 1995) has suggested that flagging theory introduces non-existent entities (e.g., make-believe tea), a state of affairs that is both confusing and unjustifiable. This argument is presented more as a warning relating to the way in which the terminology of the flagging theory is presented. Thus, Currie (1995, pp. 9) suggests that "..the flagging expression should appear as a sentential rather than adjectival modifier, as in 'It is pretend that I fill the cup with tea'". This suggestion is valid, if not somewhat precise, since Harris and Kavanaugh (1993) were clear in their explanation that the pretend episode is marked as such from the outset. However, Harris (1994) agreed with the suggestions proposed by Currie, stating that changing from an adjectival modifier to a sentential modifier "..simplifies the integration of successive pretend actions, and this is theoretically desirable.." (Harris, 1994, pp.175).

Currie (1995) makes a further criticism of the flagging theory, one which is echoed by Leslie and German (1995). Currie states that the flagging theory has no means of relating the content of the pretense to the attitudes of the individuals involved. By marking an episode as containing make-believe tea, Currie claims that the subject's attitude has been smuggled into the equation. If, on the other hand, the scenario is marked by stating that during the episode it is pretend that the cup contains tea, this will not provide any relation between subject attitude and episode content (Currie, 1995, pp.9). Leslie and German (1995, pp.14) also suggest this potential problem for the flagging theory. They argue that in effect "..flagged representations have all the properties decoupled representations have except there is no provision in the account for them to 'belong' to anyone. Unfortunately, these free-floating flagged representations do not make much sense."

In response to these criticisms, Harris (1994) points out that prior to any pretend episodes, the experimenter was involved in examples of pretend play and encouraged the subjects to engage in a warm-up period using props and toys. This had the effect of priming the children to view the scenarios as imaginary, and pretend, thus adopting an attitude at the outset towards the nature of the episodes. In this way, when flags are used to mark props in the episode, they do not make specific reference to make-believe entities, and instead refer directly to the "truth" that, for example, "the cup contains tea" (Harris, 1994, pp.177), which is encompassed by the episodinal attitude, which is "imaginary" or "pretend".

In support for this adapted theory, Harris described a study in which children between the ages of around 28 to 33 months were asked the identity of props during a pretend play episode. The children were able to not only correctly identify the make-believe status of the props, but could do so even when the status of the prop changed during episodes (e.g., a yellow building block is an "ice-cream" at one time, and a "fishfinger" at another). However, when asked if the prop was a real or a pretend "ice-cream", for example, the younger children were unable to consistently refer to the prop as pretend ice-cream, whereas the older children could identify the prop as pretend (*ibid,* pp.177). Harris argues that this demonstrates the difference between encoding a pretend status, and encoding a pretend content (*ibid,* pp.178). In other words, it is possible to know that the yellow building block is an "ice-cream" in one episode and a "fishfinger" in another, without necessarily understanding a specific attitude towards it.

Thus, whereas Leslie (e.g., 1987) sees the child as holding a specific attitude towards each separate decoupled representation, Harris (e.g., 1994) sees the child as holding an attitude towards a scenario or episode as a whole, rather then each specific instance of representation within that episode. (In further support of his suggestion, Harris points out the problems with children as eyewitnesses, due to their sometimes confusion in remembering what was actually a pretend episode as reality (1994, pp.178). This could be explained if the child held an attitude toward the overall episode, and later misremembered that attitude). The simulation hypothesis of pretense proposed by Harris and Kavanaugh presents a less complex alternative to Leslie's M-Representation hypothesis, in that it does not rely on specialised cognitive modules and mechanisms, and which offers a plausible alternative explanation of childrens participation in pretense. Simulation theory is not limited to the flagging hypothesis, however, and other proponents of simulation theory have emphasised not only pretense, but imagination as a whole.

Simulation and Imagination - Simulation theory, as was described in Chapter 1, centres a great deal of its arguments on the suggestion that simulation is fundamentally connected to imagination. That is, in order to understand other people's behaviours, and their attitudes, beliefs, fears, and so-on, one imagines being in the other person's shoes, and simulates their experiences. This simulation enables an understanding of what it would be like to experience what someone else is experiencing, since the simulation process encourages the sensations which would really be felt under those conditions. However, the simulation process is run "off-line", so even though it provides an appreciation of the feelings and mental processes of someone else, it does not lead to those feelings and processes being really acted upon (e.g., Goldman, 1989; Gordon, 1986; Currie, 1990).

Currie (1994) suggests that simulation is what underlies pretense. Children pretend by "..mentally taking on ..roles and imagining.." what it would be like to really be in that role or situation (1994, pp.8). Currie also suggests that this has a direct relation to fantasy and to enjoyment of storybook fiction, or cinema shows, etc. When the imaginary experience is simulated without overt action, this would be tantamount to fantasy, and when the written words of a book encourage related mental images this is simulation from fiction. Because simulation can deal with pretense, and can simulate possible non-veridical outcomes as options, it follows that one can simulate circumstances which are contrary to fact, and again this is something which Currie (1995) claims. In addition, Currie (e.g., 1994) does not limit simulation to pretense and fantasy imagination. He proposes that mental imagery is a by-product of simulating visual experience (an argument that is redolent of Pylyshyn, e.g., 1981), that planning of ones own goals and actions is performed by simulation, that simulating mental states of others is how one comes to understand their behaviours (and that one simulates all mental states, from beliefs to desires to intentions), and that simulation enables the experience of empathy.

In short, Currie (1994, 1995) basically claims that simulation can explain virtually everything that is addressed by this thesis, from theory of mind to mental imagery. He is also very specific about the nature of this simulation mechanism, stating that "..the imagination is the simulator....What we typically imagine is nonactual, and known to be so; imagining has connections with affect....imagining, whilst distinct from believing, has connections to both belief and desire...[and] strategy testing is..the proper function of the imagination.." (Currie, 1995, pp.11)

At first glance, Currie's proposals seem intuitively accurate. From personal experience one knows that play-acting involves behaving "as-if" one was someone-else, and feelings of empathy relate to an awareness of what it must be like to experience the things that someone-else is experiencing. Unfortunately, assuming that a simulation ability precedes such behaviours, rather than that it develops as a result of, or in relation to some other cognitive process that enables pretence, for example, raises some difficulties. A clear example is provided by Leslie and German (1995). They point out that in the case of early development of pretence understanding, a child who realises that when Dad picks up a banana and hands it to them saying "The telephone is ringing, it's for you!" is only *pretending* the banana is a telephone would, according to simulation theory, need to simulate what it would be like to be 'Dad' pretending that "telephone" means banana. In other words, simulation theory assumes an already present ability to pretend, in order to understand pretence, and to realise that Dad is not trying to teach a new word for banana (Leslie and German, 1995, pp.17-18). They argue instead that rather than being an alternative explanation to theory of mind, simulation is in fact one of the theory of mind related abilities, which develops through the use of structured, systematic metarepresentational knowledge.

They state "We see no reason to believe that simulation plays a fundamental *structural* role in theory of mind acquisition. On the contrary, simulation needs metarepresentation. However, we should not be surprised if investigation showed that "simulation" processes play other important roles, e.g., in moral persuasion, or in discovering through imagination what subtle emotional reactions one might have to a complex novel situation." (Leslie and German, 1995, pp.18).

It appears, therefore, that perhaps simulation theorists and proponents of theory of mind could develop a clearer picture of imagination if forces were to be combined, rather than seeking to offer alternative solutions to the enigma. At present, theory of mind offers a more detailed account of the cognitive development of metarepresentational ability, and it's possible relationship with imagination as explored through pretend play, whereas simulation theory offers a more detailed account of imagination as it relates not only to pretence, but also to other wide-ranging behaviours and abilities which are not currently explored by theory of mind.

5.4.ii: Imagination: Reasoning and Creativity

Reasoning - Imagination and it's role in reasoning will be explored here only briefly, since much of the literature has already been reported in Chapter 3. In Chapter 3 mental models in reasoning were reviewed, especially Johnson-Laird's theories concerning syllogistic reasoning (e.g., 1980; 1983; 1987). Although Johnson-Laird did not suggest that mental models are related to pretend representations, for example, he argued that imagination is a necessary requirement if one is to perform a reasoning task (Johnson-Laird, 1987). In short, when presented with a problem, one imagines the state of affairs described, and then imagines as many alternatives as possible that will still apply to the initial premises. Once again, there are possible confusions with the use

of the term "imagination" in Johnson-Laird's sense, but it is apparent that he relates imagination to a form of mental representation similar to theory of mind.
Also reported in Chapter 3 in relation to syllogistic reasoning in children were several studies that introduced fantasy and imagination elements (e.g., Hawkins, Pea, Glick, and Scribner, 1984; Dias and Harris, 1988; 1990; and English, 1993). These studies demonstrated the good performance shown by young children on syllogisms when encouraged to use imagination - a finding that was replicated in the counterfactual syllogistic reasoning experiment reported in Chapter 4. In each of these studies it was argued that imagination aided performance because it encouraged the children to view the syllogisms as "pretend" rather than reality, thus imagination in itself was not explained or analysed. In general, this is the case with all literature on imagination and reasoning; imagination is explored as a means of changing reasoning performance without any specific exploration of the nature of the imagination process. Most researchers assume an interpretation of imagination either as pretence or fantasy (e.g., Dias and Harris, 1988; 1990; English, 1993), or some kind of mental imagery (e.g., Bartlett, 1925; Fisher, 1916; Kaufmann, 1984).

Although these researchers agree there is an effect of imagination on reasoning performance, the earlier studies were in disagreement as to whether the effect was infact beneficial. Bartlett (1925), for example, viewed imagination as useful under certain circumstances, particularly when confronted with counterfactuals or situations which encouraged conceptual conflict. However, Bartlett also suggested that imagination could prove counterproductive to reasoning performance under circumstances where the subject relies too heavily on imaginative content rather than the original reasoning task itself, leading to a tendency to undergeneralize. This hypothesis is somewhat similar to that proposed by Johnson-Laird (e.g., 1980, see Chapter 3), who also suggested that reasoning errors could be related to the way in which the problem is originally imagined.

Fisher (1916) suggested that whilst imagination *was* utilised in reasoning tasks, subjects would invariably fall back on more propositional forms of mentalizing to successfully complete the tasks, and Kaufmann (1984) comments on the possibility that imagination is merely an epiphenomenon of more abstract cognitive processes, and in many cases could prove detrimental to reasoning if relied upon too heavily as it is often not able to logically represent the problem. These hypotheses are reminiscent of the hypotheses presented by propositional theorists - imagination and mental imagery are cognitive side-effects of a deeper abstract mental process, and in themselves are only useful in cognitive tasks such as reasoning if they do not interfere with the logical reasoning process.

It appears that there are two main approaches to imagination in reasoning. The work of earlier theorists implies that imagination is beneficial in some situations, but is generally only a cognitive epiphenomenon. Imagination might help the problem-solver in situations which are highly novel or conceptually complex (such as counter-to-fact reasoning tasks) because it encourages initial acceptance of the often unempirical ideas presented, but in relation to actual logical reasoning processes it is unnecessary. The work of more recent researchers, especially in the examination of children's reasoning performance, has highlighted an apparent advantage in reasoning with imagination, with little suggestion of any disadvantages. However, these theorists also suggest that the main benefits of imagination are to do with the way imagination encourages acceptance of counterfactuals and fantasy situations - its clarification of the context of the problem.

A further point that perhaps also should be made, is that it is possible to consider an extremely wide-range of tasks requiring problem-solving elements, which may or may not involve imagination or mental imagery. The imagery tasks that Kosslyn (e.g., 1975) presented to subjects where they were required to calculate differences in size of mental images, for example, could be argued to involve problem-solving ability, as could Shepard and Meltzer's (1971) mental rotation tasks. However imagination is considered in problem-solving and reasoning, whether general tasks or specifically logical abstract reasoning tasks, the propositional versus analogue hypotheses will both have substantiated claims to make. Imagination clearly plays a part in reasoning, and it could be argued that it is irrelevant whether it is a side-effect or a fundamental process. However, since the results of the counterfactual reasoning experiment reported in Chapter 3 demonstrated a difference in reasoning performance by children with autism when encouraged to use imagination, that was the opposite of the performance demonstrated by control groups, it remains necessary to explore that imagination process further. Results suggested a difference in the cognitive processes involved in reasoning of children with autism compared to other clinical and normally developing groups - the explanations for this difference need to be explored.

Creativity - The research that has explored imagination as relates to creativity has tended to imply that they are one and the same thing. Once again this demonstrates the current definitional problems applying to the term "imagination". It is clear from the literature that creativity is held to involve "imaginative" thought processes, and researchers have gone some way to attempting to describe those processes. Unfortunately, the descriptions do not usually refer specifically to imagination as distinct from creativity, and so any supposition of the possible nature of imagination from this work is invalid. In addition, the literature is philosophical rather than experimental, and limited in variety. Nevertheless, the descriptions of creativity are worthy of consideration, since imagination is intricately bound with creativity, regardless of the hypothesised nature of that imagination.

MacKinnon (1962) listed three linear stages to creativity. The first involved the initial conception of an original idea - this is arguably where imagination in the sense of conceiving of something non-veridical is implied. This conception is followed up by the second stage where the original idea is adapted to fit reality, so that stage three - bringing the product of the creative process into being - can be achieved. MacKinnon's (1962) hypothesis of creativity is not limited to invention of objects, but applies to creation of novel pieces of music, works of art, literature, and so-on. This is the case with all the creativity hypotheses - they can be applied not only to creative thought itself, but also to the outcomes of that thought.

Other theorists have also emphasised the relation between novel imagination and reality. May (1975) considered creativity to involve free-flowing imagination, unconstrained by reality, which is later given a more logical structure in order to express the product in the real world; whereas Suler (1980) saw creativity as an expression of primitive primary thought which is then attuned to reality.

One of the more recent hypotheses of creativity comes from Johnson-Laird (1987). Johnson-Laird outlines three factors of creativity: (i) the creative process does not depend on the simple recollection of an already existing idea; (ii) the creative product is not simply the result of mental calculation or other deterministic mental process (humans can make arbitrary choices); (iii) creative products must meet some already existing criteria or constraints (Johnson-Laird, 1987, pp.122). Johnson-Laird suggests that by following his definition of creativity, there are only three possible explanations of the creative mental process. He assumes that the creative process needs to start with some existing "building blocks" (elements) (pp.124), which are non-deterministic but meet some already established criteria. These building blocks can then be treated in one of three possible ways. The "neo-Darwinian" explanation is that the building blocks are combined in a totally arbitrary way, producing some nonsensical results which have to be filtered out according to real-world constraints before a truly creative product can be found. The "neo-Lamarckian" explanation is that the creative elements are combined and modified according to real-world constraints, and *then* selection between the outcomes is made.

The multi-stage explanation is that criteria and constraints are applied both in the initial generation of combined creative elements, and also in the later selection of the final products. In this final example, Johnson-Laird suggests it is also possible to include feedback between the various stages of combination and selection according to constraints. This final explanation is the one favoured by Johnson-Laird (1987), and he demonstrates its application using musical improvisation as an example - music is constrained in generation by the tonal relations between various chords, and then by the knowledge of what level of change in notes produces a pleasing melody, or what speed of playing would sound best. These constraints interrelate, and ultimately a creative product is produced which is both novel, but guided by certain existing criteria. Although Johnson-Laird (1987) uses musical improvisation as an example of a multi-stage creative process, like other theorists he suggests that it applies equally to creation of novels and paintings, as well as to reasoning processes. Once again, it is a general model of creativity that has been presented.

Creativity has been related to imagination through definition, although there are clear differences between the two. Creativity concentrates more on the product outcome than the initial cognition, and it appears from the models outlined above that imagination is really only involved in the early stages of creativity as defined here. Reports of symptoms of autism often suggest lack of creativity as well as lack of imagination. It may be that it is the imagination alone that is deficient - forming a mental representation of something novel and/or non-veridical - rather than any other part of the creative process. Thus, although creativity is related to imagination, as is reasoning, these are aspects of imagination that are less clear-cut and well-defined than mental imagery and pretense. They have been included in this review because to ignore them would be to fail to cover aspects of imagination as currently defined, but perhaps through their inclusion it has also helped to clarify the need to differentiate more clearly what is referred to by the term "imagination" in different contexts.

Studies of imagination in normal development, especially pretense and simulation, have helped demonstrate the fundamental way in which imagination is involved in cognitive development and cognitive processes. It is possible to see similarities between hypotheses of mental imagery and hypotheses of metarepresentation and simulation, supporting the suggestion that imagery and imagination are closely related.

Having explored the literature on imagery and imagination in normal development, this review will conclude with an exploration of the literature on imagery and imagination in autism.

5.5: Imagery, Imagination, and Autism.

As was the case with the reasoning and autism literature outlined in chapter 3, there are relatively few studies of imagery and imagination in autism either. This may seem unusual since lack of imagination is a diagnostic criteria for autism, and most other diagnostic features of autism have undergone scrutiny and experimental testing. However, imagination is perhaps not the easiest ability to study, and the apparent lack of imaginative behaviours in autism is so widely accepted it perhaps has been overlooked as a necessary area of research. This is not to say that imagination and mental imagery have not been studied at all in autism - there have been a number of studies of pretense in autism, and some exploration of veridical mental imagery. Nevertheless, this appears to be virtually the sum of research in the areas of imagery and imagination, thus the questions that were raised by the findings of the

Counterfactual Syllogistic Reasoning task in chapter 4 concerning non-veridical imagery, for example, cannot be answered from the current literature. However, this review will now continue with an exploration of the research in imagery and imagination in autism to date, before presenting further experiments in imagery and imagination in autism.

5.5.i: Visual Imagery Studies in Autism

Beate Hermelin (e.g., 1976) put forward the suggestion that children with autism may lack "inner pictures", and may be unable to internally represent their external environment. (This is a similar suggestion to that posited in the discussion of the Counterfactual Syllogistic Reasoning task presented in chapter 4, that the subjects with autism may have performed poorly in the imagination condition due to an inability to form the required "pictures in the head"). Hermelin presented a series of imagery studies which tested this possibility. O'Connor and Hermelin (1973) presented deaf children, normally developing children, and children with autism with a test of spatial visual memory. The children were shown a visual presentation of three letters, presented left, centre, and right on a screen. The letters appeared successively, and were presented in such a way that the left-to-right spatial positioning did not coincide with the temporal order - i.e., the letter presented first was not presented in the left position. Thus, the subjects could either recall the letters in first to last temporal sequence, or left-to-right spatial sequence. O'Connor and Hermelin (1973) found that whereas normally developing children would recall the letters in temporal sequence, the deaf children and children with autism predominantly recalled the letters in spatial left-to-right sequence, suggesting that these groups stored a visual image of the display, from which they "read off" the letters from left to right.

To test the findings further, O'Connor and Hermelin (1973) presented the subjects with another study. In this experiment numbers were presented in the same conditions as before, but instead of free-recall the subjects had to select a number on a card which displayed the numbers in either spatial sequence or temporal sequence, coupled with a "random" display (e.g., if presented with the numbers 3,5,9, in temporal sequence, but 9,3,5, left-to-right spatial sequence, the choice cards would show either 359 and the random 593, or 935 and 593). Thus, O'Connor and Hermelin tested the favoured method of storage for each subject, and whether the other method would be used if the favoured option was not presented. They found that the deaf subjects and the children with autism consistently favoured the spatial presentation over the temporal, whilst the normally developing children favoured the temporal over the spatial, and that when the favoured option was unavailable there was no preference for it's opposite over the random option, suggesting that the storage methods were specific. Findings therefore confirmed that the children with autism were apparently forming a visual/spatial image of the materials presented.

O'Connor and Hermelin (1975) also presented children with autism, and normal and blind controls, with mental rotation tasks. The first task required the sighted subjects (normal and autistic) to be blindfolded. The subjects were presented with pairs of two-dimensional shapes mounted and fixed in position on a board, with a gap inbetween the two shapes. The subjects had to decide whether the two shapes would fit together "jigsaw style", or were incompatible. Some of the pairs were presented such that one shape would fit if turned through a particular angle or inverted. Since the shapes could not be moved, the task required the subjects to "mentally rotate" the second shape to decide if it would fit. In addition, subjects were later required to decide if a model of a hand which was presented to them was that of a left or a right hand, whilst blindfolded. O'Connor and Hermelin (1975) reported that the subjects with autism performed as well as both control groups with the shapes, although the normally developing children were faster than the other groups at identifying hand shapes. (It is interesting to note that the blind subjects performed as well as the other subjects, supporting the hypothesis that imagery is not solely visual by nature.)

In an unpublished study, Shah (1988) provided further evidence that children with autism can perform comparative to controls on tasks of mental rotation. Shah based her experiments on those of Shepard and Meltzer (1971) presenting subjects with pictures of three dimensional pairs of objects, and requiring the subject to decide if the objects matched each other. Shah (1988) found no significant differences in performance between the children with autism in her study and control groups.

A further test which arguably requires spatial imagery ability is the Block Design subtest of the Wechsler Intelligence Scales (Wechsler, 1974; 1981). This test has been presented to children with autism (e.g., Prior, 1979; Lockyer and Rutter, 1970; Shah and Frith, 1993) with the consistent finding of *superior* performance by these subjects compared to normal and mentally handicapped controls. For example, Shah and Frith (1993) presented twenty children with autism, and matched normally developing and mentally handicapped controls, with 40 block designs to construct. Some of the designs were presented rotated, some unrotated, some pre-segmented, whilst others were presented whole. Shah and Frith found that the children with autism performed comparably to controls in all conditions except in the condition where the subjects worked from a whole rather than a pre-segmented block design. In this condition the performance by the subjects with autism was superior. Shah and Frith (1993) suggested that the findings demonstrate normal visuo-spatial abilities in subjects with autism, and they hypothesised that the superior performance in the whole-block condition may be a result of weak central coherence. (See chapter 1 for a fuller explanation of the weak central coherence hypothesis of autism). Thus, evidence from Block Design tasks also suggests visuo-spatial imagery ability in autism.

It is evident from the studies reviewed above that visual and spatial imagery in autism is unimpaired. However, with the exception of the letter-sequencing study by O'Connor and Hermelin (1973), none of the experiments required the subjects to deal with imagery for absent objects - each task was performed with the stimulus available either to touch or to vision. It could be argued that this raises the question about whether the subjects with autism were truly utilising imagery to perform the tasks, as opposed to perceptual information alone. Anecdotal evidence of autistic savant artists, such as Stephen Wiltshire who draws detailed and accurate representations of buildings from memory (see e.g., Baron-Cohen and Bolton, 1993, pp.56-57) suggests that visual imagery in memory may be intact, but savant artists do not represent the majority of children with autism. Sigman (1987) presented evidence that children with autism are comparable to controls in their ability to locate an object by searching for it in its last known position, implying that children with autism do form mental representations of absent objects, and utilise visual imagery in memory, but since there is limited evidence in this area further studies of visual imagery in the absence of perceptual input are required. However, as the evidence stands it suggests that there is no deficit in autism in the ability to form veridical mental images, as tested by traditional imagery tasks such as mental rotation.

One final study that relates to mental imagery in autism was conducted by Hurlburt, Happe, and Frith (1994). This experiment examined three adults with Asperger Syndrome, a syndrome in which the individual has core autistic symptoms but is of at least average intelligence and language ability. (There is some debate as to whether Asperger Syndrome is truly related to autism or not, but this debate is not discussed further here.) Hurlburt et al. asked the subjects to record the content and nature of their thoughts at specific intervals during the day (signalled by a beeper the subjects were carrying). They found that all three subjects reported thoughts primarily in the form of images - normal adults report a variety of thoughts including imaginal, linguistic, and abstract. Although this study looks at Asperger sufferers, and only has a sample of three subjects, it is of interest since it raises the possibility that children with autism are capable of mental imagery. An interesting point to note from the study is that the kinds of images reported were always veridical, either visual memory images or images of the subject's present situation from another angle.

As was the case with the literature on normal development and imagery, there are no studies of non-veridical mental imagery and autism. However, studies relating to imagination have been presented, exploring the production of pretense by children with autism.

5.5.ii: Studies of Imagination in Autism

There have been several studies presented in recent years which demonstrate a lack of spontaneously produced pretend play by children with autism (e.g., Riguet, Taylor, Benaroya, and Klein, 1981; Ungerer and Sigman, 1981; Sigman and Ungerer, 1984; Baron-Cohen, 1987; Gould, 1986; Charman and Baron-Cohen, in press). For example, Sigman and Ungerer (1984) presented children with autism, and matched mentally handicapped and normally developing controls, with various toys, including dolls, toy cars/trucks, a hairbrush, a mirror, toy furniture, and so-on. Before the children were allowed their own access to the toys the experimenter modelled acts of pretend play, such as feeding a doll pretend food. The subjects were then allowed to play alone with the toys for a specified period of time. Sigman and Ungerer (1984) were interested in recording the types of play behaviours that were exhibited, such as *functional play* (where the child simply uses the toy in a manner representative of real function - for example, moving a toy car along the ground and making engine noises), and *pretend play* (for example, performing a scenario with invisible/imaginary objects or substituting one object for another). Sigman and Ungerer were also interested in whether the play was directed more often towards a certain kind of toy, such as the dolls rather than the cars and furniture. Results demonstrated that whilst the children with autism were comparable in their production of functional play, they produced significantly less pretend play than the two control groups. Sigman and Ungerer (1984) also noted that the children with autism directed a greater proportion of their attention to the toy cars and furniture, for example, than to the dolls - a behaviour they suggested may represent the preference of people with autism for "inanimate" objects over people.

Baron-Cohen (1987) presented children with autism, and matched mental handicap (Down's Syndrome) and normally developing controls, with three sets of toys in separate sessions. The toys included: (i) cuddly toy animals, and building blocks of varying shape and size; (ii) a toy stove with toy pots and pans, spoons, a doll, and small pieces of green sponge, plus a toy telephone; and (iii) some small toy figures and toy playground equipment. The subjects were seen individually and given one set of toys at each session, in a random order, and the child was observed for fifteen minutes with each toy set.

Baron-Cohen (1987) coded the child's behaviour in four ways: (i) *sensorimotor* - simple manipulation and/or sensual use of the objects (e.g., sucking) with no regard for their nature; (ii) *ordering* - imposing pattern on the toys, such as stacking on top of each other, or lining up; (iii) *functional play* - demonstrating knowledge of the appropriate function of the toy; and (iv) *pretend play* - substituting the object for another, creating imaginary objects, attributing properties to the object which are not real.

Results showed that whereas the 80-90% of the Down's syndrome and normally developing children demonstrated pretend play, only 20% of children with autism did so. The children with autism produced mainly sensorimotor and functional play (80% and 100% of the group, respectively). In fact, when compared with the Down's syndrome subjects alone, the only significant group differences were in production of pretend play, a result which Baron-Cohen suggested demonstrates the autism-specific nature of lack of spontaneous pretend play - the deficit is not due to clinical mental age.

In addition to the studies which have clearly demonstrated a deficit in the spontaneous production of pretense by children with autism, some studies have shown evidence of production of pretend play by children with autism during prompted and/or structured conditions (e.g., Lewis and Boucher, 1988; Jarrold, Boucher, and Smith, submitted; Jarrold, Boucher, and Smith, 1994). For example, Lewis and Boucher (1988) presented children with autism, and matched clinical and normally developing controls, with toy cars and toy garages, and asked the children to demonstrate what they could do with the props. Children with autism were not significantly impaired in appropriate production relative to controls. However, this particular experiment has been criticised (e.g., Jarrold, Boucher, and Smith, 1994; Charman and Baron-Cohen, in press) because the props could only be combined in certain ways (e.g., putting the car in the garage), and this kind of behaviour is more commonly termed "functional play". Also, the ages of the children with autism were particularly high in Lewis and Boucher's sample (mean of around 10 years of age), compared to other pretend play studies in autism. Although the majority of studies with children with autism bases the sample on verbal mental age rather than chronological age, it is possible that older children may have either developed further or had more experience in situations encouraging production of pretense.

Jarrold et al. (1994) presented a study designed to cater for the earlier criticisms. They presented younger children with autism (aged from around 5 years of age, up to eleven years), and matched clinical controls with sets of toys, either doll figures alone, lego building blocks, or dolls plus junk objects (such as a piece of sponge, and a matchbox covered with foil, for example). Children were either left in a free-play situation with the toys, or prompted by the experimenter saying, "What can you do with these?", for example. Jarrold et al. (1994) reported that whilst the children with autism produced less pretend play in the spontaneous, free-play condition, the production of pretense was not significantly different to controls in the prompted play condition. An interesting point to note with this study, however, is that the children were scored as producing pretend acts of object substitution if they used the lego blocks to build houses, cars, and so-on. The majority of the play time spent by children with autism was with these building blocks, and it is possible that receiving specific instruction to show the experimenter what they can do with the blocks led to some subjects with autism building houses, etc. - a behaviour that can only tentatively be labelled "object substitution", since that is what is *done* with lego blocks, and there is no evidence that the children with autism were "pretending" the blocks were houses rather than simply using the blocks in the only way they knew how.

In a later study, Jarrold et al. (submitted) presented children with autism and matched mental handicap controls with only dolls figures plus junk materials, similar in content to those used in the previous experiment. Again, the children were either left to play spontaneously or were prompted by the experimenter. In this experiment, Jarrold et al. found that the children with autism were impaired, relative to controls, in producing both spontaneous *and* elicited pretend play. However, Jarrold et al. then followed up this initial task by presenting the subjects with dolls and "props" (e.g., a matchbox covered in wrapping paper, a small plastic football, etc.) and giving specific instructions which the subjects had to try and perform (for example, "show me how the boy throws a ball to mummy", or "show me how the girl can be excited about the present"). This time, Jarrold et al. found no differences in production of pretend acts by the two groups under such structured conditions where appropriate props were available. (Findings also support suggestions that children with autism are capable of understanding certain basic emotions, such as fear, happiness, etc. - e.g., Baron-Cohen, 1991d).

Jarrold et al. concluded that under conditions where children with autism are given specific instruction and structure to follow they will produce evidence of pretend play, thus suggesting that the pretend play deficit in autism is due to a generativity problem and not a theory of mind/metarepresentational deficit. A final study by Jarrold et al. (submitted) demonstrated that when provided with props but not given specific instruction, rather simply asked to try and pretend something, children with autism again demonstrate a deficit compared to controls, further supporting Jarrold et al's. generativity deficit hypothesis. (This finding is similar to that of Charman and Baron-Cohen, in press, who demonstrated that under structured conditions with props children with autism could produce situationally-appropriate object substitution, but were impaired in production of novel or unprompted pretend acts. Thus, Charman and Baron-Cohen argue that structured object-substitution under such conditions is not evidence of pretense proper, but simply of showing that the autistic child can perform "intelligent guessing").

Jarrold, Smith, Boucher, and Harris (1994) presented further evidence for the generativity deficit hypothesis by demonstrating that children with autism can *understand* pretend acts when performed by another. They showed children with autism, and matched mental handicap and normally developing controls, a series of episodes by "Naughty Teddy". The episodes were either literal or pretend (counterbalanced) and involved Naughty Teddy pouring or squirting a substance over a target, either in pretence or reality. (For example, really pouring orange juice from a bottle onto the target, or pretending to squirt toothpaste from a tube onto the target.) The subjects were asked: (i) substance questions (e.g., "what did Naughty Teddy put on [the target's] head?"), (ii) outcome questions (e.g., "Is [the target] wet or dry now?"), and (iii) mode questions (e.g., "Did Naughty Teddy put *real* [substance] on [the target] or only *pretend*?"), (Jarrold et al., 1994, pp. 7).

Jarrold et al. (1994) found that the children with autism showed no significant difference compared to controls in their ability to answer the three question types presented. However, results also showed that the groups were guessing their mode question responses, and that they performed less well with the outcome questions if the pretend episode was presented second. A further possible criticism is that it may be possible to correctly answer the questions without understanding pretense at all, but rather by following causal reasoning of the actions (causal reasoning being something with which children with autism are capable of dealing, as demonstrated in chapter 3 of this thesis).

A similar criticism can be applied to a study by Kavanaugh and Harris (1994) which has been suggested as demonstrating understanding of pretend causal transformations. In this study, children with autism and matched clinical controls were shown episodes of pretend transformation (e.g., the experimenter pretended to pour tea from a teapot onto a toy duck), then asked to select a picture from a choice of three, which depicted the way the duck would now look (e.g., picture of duck as is; picture of duck covered in tea; picture of duck covered in red triangles). The children with autism demonstrated an ability to choose the relevant pretend transformation picture, and Kavanaugh and Harris suggested that this shows that children with autism have an understanding of representational imagination. The major criticism to this study has already been outlined, but another potential problem comes from the fact that the children with mental handicap scored *less well* than the children with autism - a result that raises doubts as to whether the study was really tapping pretense and imagination at all. However, allowing for the possible methodological criticisms, the studies by Jarrold et al. (1994, submitted) and Kavanaugh and Harris (1994) still raise some possibility that children with autism may only have a deficit in generation of pretense rather than understanding - a possibility that needs to be explored further in the future.

A final hypothesis for autism to report is from Currie's (1994; 1995) explanations of simulation theory. Currie suggests that individuals with autism have a defective simulator, and that this is what leads to their problems with mental state understanding, production of pretend play, planning of future actions, and imitation, since he argues that each of these abilities requires the ability to simulate either your own possible future actions, or the behaviours of others. He also suggests that deficits would be found in any other areas which he claimed require simulation, such as visual imagery which, according to Currie, is simulation of the visual system. In other words, simulation theory predicts that children with autism will be unable to perform successfully on tasks that require mental imagery of any description, since they do not possess an efficient "simulator" mechanism.

In summary, the studies conducted thus far on mental imagery and imagination in autism suggest that veridical mental imagery is probably intact (with the exception of the claims made by Currie), and that there is a deficit in imagination as relates to pretense, certainly in it's spontaneous production, and probably also in true understanding. However, it is also clear that imagery studies and imagination studies have been limited. A fuller exploration of mental representation in imagery and imagination in autism is required, confirming the supposed intact veridical imagery processes, especially in the light of simulation theory claims, and exploring non-veridical imagery and imagination under spontaneous and instructed conditions. The next chapters present a series of five experiments exploring imagery, imagination, and generativity in autism.

CHAPTER SIX

Two Experiments Exploring Veridical Imagery in Autism.

Evidence from the literature suggests that people with autism do not have a deficit in the ability to utilise imagery of current empirical items or situations - they are able to perform tasks of mental rotation (e.g., Shah, 1988) and they are able to appreciate another persons visual perspective (e.g., Baron-Cohen, 1989a), both of which arguably involve a degree of imagery. However, because results in Experiment 3, the Counterfactual Reasoning experiment, suggest that the children with autism did not understand the nature of mental images and had difficulty in spontaneously imagining non-empirical things such as flying pigs, the possibility that they were unable to utilise mental imagery at all is still open to question. The imagination training questions employed in the experiment could not ascertain for certain whether imagery was being used when the children were asked to imagine flying pigs - they could have relied on knowledge of the concepts involved to respond to the questions without using imagery. Although this broad explanation for the deficits in performance by the children with autism in the imagery condition was argued as unlikely, due to the paucity of research in this area it is important to explore veridical imagery in autism further before conducting an examination of non-veridical imagery ability. In this way the assumed presence of veridical imagery processes in autism can be affirmed or denied and subsequent experiments can attempt to narrow the area of exploration.

6.1: Experiment 4 - Visual Memory: "The Chessboard"

One way to explore imagery of real objects and veridical situations is by using tasks that examine visual recall or visual memory (Levine, Warach, and Farah, 1985; see Farah, 1988, for a review). Tasks such as these require the subject to remember in detail something that has been seen, and in some cases to reproduce that remembered perception. This can be as part of a long-term memory of a well-known object or a short-term memory for something seen only recently (see Kosslyn, 1994, pp 289-291). These tasks also explore a different use of mental imagery to the mental rotation and perspective understanding tasks which have previously been used with subjects with autism, thus enabling a more widespread overall exploration of imagery abilities in autism.

The Chessboard experiment described here is similar to an experiment conducted by Barbizet and Cany (1968). They presented normal adults and adults with multiple sclerosis with a chessboard on which 7 poker chips were placed. After one minute the chessboard was hidden and the subject had to match the position of those poker chips on another chessboard. If the subject was unable to master the task within 15 trials, the task was presented once more using only 3 poker chips. Barbizet and Cany found that normal adults on average successfully matched 4 poker chips after the first trial, whilst adults with multiple sclerosis performed significantly worse, having difficulty consecutively matching 3 poker chips after the full 15 trials.

Barbizet and Cany (1968) suggested that poor performance by subjects with multiple sclerosis was due to these subjects being unable to mentally visualise spatial relationships, or having poor visual memory in general.

The aim of the present Chessboard experiment was to explore visual imagery for a veridical situation. It was predicted that results would support other studies that have touched upon veridical imagery in autism, such as object-permanence tasks (e.g., Sigman, 1987), and mental rotation tasks (e.g., Shah, 1988), and that the subjects with autism would be comparable to controls in their ability to utilise imagery in a visual recall task.

A further prediction was that around 5% of the subjects with autism may exhibit superior performance to controls on this task. This prediction follows claims that around 5% of people with autism have savant abilities (e.g., Frith, 1989; O' Connor & Hermelin, 1988), and that these abilities are often seen in the area of visual memory (e.g., Stephen Wiltshire, who is able to reproduce a precise drawing of a building from memory after looking at it for a brief period of time - see Baron-Cohen & Bolton, 1993).

6.1.i: Method

Subjects - The subjects were as described in chapter 2, subjects for experiments 4 to 8 (see Table 2:2).

Materials - The materials for this experiment consisted of two fold-up chess/draughts boards (approximately 30 cm square), and ten draughts pieces of the same colour. In addition, pieces of black card, cut appropriately, were used to cover parts of the chessboards when the full size was not needed. A dark coloured teatowel was also used to hide one chessboard from view as necessary.

Design and Procedure - Each subject was seen individually, in a quiet room in their school. The subject was shown the two chessboards, laid side-by-side, and told that they had to try and match the patterns on the chessboards. At this stage, the chessboards were partially covered using cardboard so that only four squares were visible on each (2 white and 2 black, see Appendix 9).

Training and Instruction phase - The experimenter first gave a demonstration, placing one draughts piece on the board infront of her, and explaining "Let's look carefully at which square the draughts piece is on. Now I'm going to cover up the board, and let's try and put another draughts piece on your board in the same place, so that both the boards match." The experimenter then covered the board with a teatowel, and gave the subject a draughts piece to place on the other board. After the subject had placed the draughts piece, the teatowel was removed from the original board, and the experimenter said "Well done, that's right! Both the boards look the same, they match." or "Well, that's nearly right, but we should put the draughts piece here so that both the boards look the same. See, now they both match." This demonstration was repeated twice to ensure the subject understood the instructions.

Test phase - Once the subject had successfully completed the Training and Instruction phase, the experimenter began the task. The instructions used were as before. The subject had one minute to study the chessboard after the experimenter had laid the draughts piece on the first board.

In order to make the task as easy as possible for the subjects, the task progressed in stages: (1) 2 x 2 board, (2) 3 x 3 board, and so-on up to the full size chessboard. Once the full board had been achieved, the subject was then asked to match 2 draughts pieces on the full board, then 3 draughts pieces, and so-on until a maximum of 5 pieces had been matched. (Five pieces on a full size chessboard was deemed sufficient as a maximum, since the probability of correctly placing just one piece by chance on a full-size chessboard was 0.00002.) In order to successfully pass a given stage, the subject was required to correctly match the draughts pieces on three consecutive trials.

6.1.ii: Results

The performance by both the clinical groups on this task was relatively poor. 73.3% of children with autism, and 71.4% of children with mental handicap only matched at the lowest level of the task - one draughts piece on a 2x2 board. In contrast, only 33.3% of the normally developing subjects were unable to progress beyond this stage. The difference between the two clinical groups was not significant (Autism x MH, Chi-square = 0.014, $p>0.75$). Both clinical groups performed significantly worse than the normally developing controls (Autism x Normal, Chi-Square = 4.84, $p<0.05$; MH x

Normal, Chi-square = 4.21, $p<0.05$). Table 6.1 shows the number of subjects completing each stage, in each group (see Appendix 10).

Table 6.1 : Maximum stage completed by subjects in each group.

Group	2x2 board	3x3	4x4	Full board (1 draught)	Full board (2 draughts)	Full board (3 draughts)
Autism	11	0	0	1	1	2
MH	10	0	0	3	1	0
Normal	4	2	2	5	1	0

It is clear from the Table that the majority of clinical subjects performed at the lowest stage. However, the probability of passing the 2x2 board by chance was 0.25 for each trial. Since the subjects had to successfully pass 3 trials in order to complete a stage, the probability of completing the 2x2 stage was 0.016, thus both clinical groups were performing well above chance. Following the prediction concerning savant abilities, it is of interest to note that two of the subjects with autism successfully passed the final stage, matching 3 draughts pieces on a full-size chessboard. This is an impressive performance, which was unmatched by the control groups, and is possibly explained by savant abilities. As was mentioned earlier it has been suggested that around 5% of people with autism have savant abilities (Frith, 1989; O'Connor & Hermelin, 1988), and it may be that these two subjects had strengths in this kind of visual memory task.

6.1.iii: Discussion of Experiment 4

The results of the Chessboard experiment appear to support the prediction that children with autism would perform comparably to controls on a task involving visual recall. There was no difference in performance between children with autism and children with mental handicap, with both clinical groups performing above chance in completing the 2x2 stage of the experiment. The results also suggest that children with autism are comparable to clinical controls in their understanding and visualisation of spatial relationships, which is one of the areas tapped by this task. This supports previous studies such as visual perspective taking tasks (e.g., Baron-Cohen, 1989a, 1991b; Tan & Harris, 1991) where children with autism show an understanding of what can be seen from various angles and positions, for example.

However, although the Chessboard experiment was designed to explore the abilities of children with autism in utilising visual imagery to pass a visual memory task, the task produced a low level of performance from both the clinical groups and is thus insufficient alone as an argument for the existence of veridical mental imagery in children with autism. It is possible, for example, that the task could be successfully completed at the 2x2 stage by remembering a specific rule for each trial, such as "The draughts piece must be placed on the top left square, which is white". This kind of memory does not necessarily require a visual mental image.

Furthermore, it is possible that attention span may have been a contributing factor in the failure of the majority of clinical subjects to proceed beyond the 2x2 stage, with the task demands being too high for these subjects. A one minute period in which to study the original board was selected so that the subjects had every opportunity to take in the information, but it may have been that this length of time distracted from the task at hand with some of the clinical subjects.

Results suggest that children with autism are as capable as matched clinical controls in utilising veridical visual imagery in a visual recall task, but to further strengthen this conclusion another task exploring veridical visual imagery, and visual memory, was presented.

6.2: Experiment 5 - Visual Memory: "Complex Pictures".

The Complex Pictures experiment was designed to be less arduous for the subjects by being more like the kind of game that might be played in a school or home environment. Also, it was designed to reduce the likelihood that the task could be passed simply by utilising a mental rule instead of utilising visual mental imagery abilities. Again it was predicted that the children with autism would show comparable performance to controls, further supporting the evidence that these children have intact veridical imagery processes.

6.2.i: Method

Subjects - Subjects were again as reported in chapter 2 (see Table 2:2).

Materials - Materials consisted of 2 colour photographs, each depicting a detailed scene. One picture concerned a situation that the subjects would be familiar with (a snow-scene with people involved in various activities in the snow), whilst the other picture concerned a situation that the subjects would be less familiar with (African tribesmen, women, and children, performing various tribal activities and celebrations). A tape-recorder was used to record the subjects' responses, for later analysis.

Design and Procedure - The experiment had two conditions: Memory condition and Story condition. Each subject received both conditions on separate occasions, with the presentation of conditions and of photographs being counterbalanced across subjects. (Thus, half the subjects received the Memory condition first - with half of those seeing the Snow-scene, and half the African scene; and half received the Story condition first - again, half of those seeing the Snow-scene first, and half seeing the African scene). Subjects were seen individually in a quiet room in their school.

Memory condition - For the Memory condition, the subject was told by the experimenter "I am going to show you a picture, and then I want you to try and remember as much of the picture as you can." The subject was shown the photograph for one minute, and then it was hidden from view and the subject was asked "Now, I want you to tell me as many things as you can that you remember about the picture.

What was in the picture?" The subject was allowed two minutes to recall things, and was prompted during that time with the experimenter saying "That's good. What else do you remember about the picture?"

Story condition - For the Story condition, the subject was told "I am going to show you a picture, and then I want you to tell me a little story about what was in the picture." As in the Memory condition the subject was shown the picture for one minute before it was hidden from sight. The subject was then asked "Now, I want you to try and tell me a little story about what was in the picture." As for the Memory condition, the subject was allowed two minutes to respond, and was prompted during that time with the experimenter saying "That's good. Tell me some more of the story about the picture."

The two conditions were designed to explore whether subjects would be more general or more specific about the contents of the photographs under different circumstances. The two pictures were chosen to explore whether subjects would produce more responses for a familiar scene as opposed to an unfamiliar scene.

It was predicted that the subjects with autism may give more specific responses than controls, for example listing small details in the photographs, regardless of the condition or whether the picture depicted something familiar. This prediction followed claims by the proponents of the weak central coherence hypothesis of autism that subjects with autism tend to see separate parts as opposed to the whole (e.g., Frith, 1989; Shah & Frith, 1983) concentrating on individual details rather than an overall impression.

Scoring - A record was taken of the number of things correctly remembered from each photograph, and whether it was a specific detail or a description of something over-all. Thus, each subject received a score of (1) how many things were recalled, and (2) how many of those things were specific details, and how many were overall impressions of the whole scene.

6.2.ii: Results

Results first compare the total number of items recalled by each subject group, and then analyse the way in which the material was recalled (see Appendix 11).

Memory condition - Total number of things recalled - 73.3% of the subjects with autism recalled a maximum of 2 things about the photograph they saw (mean number of items recalled = 2.27; range 0-7), as compared to 50% of the subjects with mental handicap (mean number of items recalled = 2.64; range 0-5) and 6.7% of the normally developing controls (mean number of items recalled = 4.47; range 1-6). The difference between the two clinical groups was not significant (Autism x Mental Handicap, Chi-Square = 1.68, $p>0.25$). The normally developing controls performed significantly better than both the children with autism (Normal x Autism, Chi-Square = 13.9,

$p<0.001$) and the children with mental handicap (Normal x Mental Handicap, Chi-Square = 6.81, $p<0.01$).

Story condition - Total number of things recalled - In this condition, 66.7% of the subjects with autism recalled a maximum of 2 things (mean number of items recalled = 2.2; range 0-6), compared to 50% of the subjects with mental handicap (mean number of items recalled = 2.71; range 0-6) and 14.3% of the normally developing subjects (mean number of items recalled = 4.29; range 2-7). As in the Memory condition, the difference between the two clinical groups was not significant (Autism x Mental Handicap, Chi-Square = 0.84, $p>0.5$), whereas the normally developing subjects performed significantly better than both clinical groups (Normal x Autism, Chi-Square = 8.9, $p<0.005$; Normal x Mental Handicap, Chi-Square = 4.56, $p<0.05$).

Memory plus Story Conditions - Since the performances by all three groups were almost identical in the number of things recalled in each condition, a one-way analysis of variance was conducted on the combined scores from both conditions to see if the results remained the same: Anova, Autism x Mental Handicap x Normal, $F(2,40) = 9.82$, $p<0.01$. Scheffe comparisons confirmed that the clinical groups were not significantly different in their performance (Autism x Mental Handicap, $F(2,40) = 0.77$, $p>0.5$), whereas the normally developing controls performed significantly better than both the subjects with autism (Normal x Autism, $F(2,40) = 17.56$, $p<0.01$) and the children with mental handicap (Normal x Mental Handicap, $F(2,40) = 10.96$, $p<0.01$).

Memory Condition - Number of specific details recalled - For the subjects with autism, 29.4% of the total number of things recalled were specific details (e.g., "There was a boy with a yellow boot") as opposed to overall impressions (e.g., "It was snowy"). This was compared to 29.7% for the children with mental handicap, and 56.7% for the normally developing children. The number of subjects with autism who recalled specific details was significantly lower than normally developing controls (Autism x Normal, Chi-Square = 6.64, $p<0.01$) but not than subjects with mental handicap (Autism x Mental Handicap, Chi-Square = 2.77, $p>0.1$).

Story condition - Number of specific details recalled - In this condition, for the subjects with autism 18.2% of the total number of things recalled were specific details, compared with 15.8% for the children with mental handicap, and 66.7% for the normally developing children. Again, the subjects with autism performed significantly worse than the normally developing children (Autism x Normal, Chi-Square = 13.9, $p<0.001$) but not than the children with mental handicap (Autism x Mental Handicap, Chi-Square = 0.28, $p>0.75$).

6.2.iii: Discussion of Experiment 5.

The results of the Complex Pictures experiment support the previous results from the Chessboard experiment - children with autism are comparable to matched clinical groups in their performance on these tasks. Again, performance by the two clinical groups was low compared to that of the normally developing controls, but this may be a result of attention span rather than a deficit in visual imagery and visual memory for real things, although it could be argued that neither experiment tests veridical imagery.

It is clear from the results that the majority of subjects with autism and subjects with mental handicap were recalling overall details from the test photographs, such as "They were all wearing grass skirts" for the African Scene, or "It was all white and snowy" for the Snow Scene. Supporters of the hypothesis that mental images are propositional in their nature (e.g., Pylyshyn, 1981) may argue that such general impressions do not require imagery for recall but rely purely on descriptive memory, although this seems an unlikely argument considering the large amount of evidence from neuropsychological studies supporting the hypothesis that visual memory incorporates imagery (e.g., Kosslyn, 1973; Kosslyn, Ball, & Reiser, 1978; Finke & Pinker, 1982;1983), and that this imagery is pictoral rather than propositional (e.g., Le Bihan, Turner, Zeffiro, Cuenod, Jezzard, & Bonnerot, 1993; Farah, Soso, & Dasheiff, 1992; Bisiach & Luzzatti, 1978; Roland & Friberg, 1985).

The finding that subjects with autism did not recall a greater number of specific details compared to controls was surprising, considering the well-documented arguments that people with autism are superior in their performance on tasks that involve locating a small part of an overall picture (e.g., Shah & Frith, 1983), and anecdotal evidence concerning reports of children with autism finding very small items that have been dropped on a patterned carpet, for example (e.g., see Baron-Cohen & Bolton, 1993). Reports and studies such as these have led to Frith (1989) putting forward the hypothesis that people with autism have a deficit in "central coherence", that is, they are unable to bring together pieces of information to form a whole (see Chapter 1) - something which she argues is fundamental in normal cognitive information processing. However, the findings from the present experiment suggest that children with autism may not preferentially focus on individual details, and are as likely as controls to take in general information from a stimulus. However, performances were very low from some subjects, and these floor levels cannot support this suggestion.

Contrary to the original predictions, the results from this experiment gave no evidence to support the idea that subjects may perform differently under two varied conditions, following different kinds of instruction. All three groups recalled almost identical numbers of things from the test photographs, regardless of whether the condition was Story or Memory. However, this experiment made no record of the number of things "recalled" that were *not* in the test photographs, and this was perhaps the element that changed across the two conditions. Although there was no formal analysis, experimenter notes during the experiment suggested that the normally developing children produced more false responses as they *told a story* about the photograph in the Story condition, that involved imaginative ideas. This was not noted with the children with autism. This is perhaps a consideration for future studies of this kind, but since this experiment was specifically interested in the veridical and accurate visual memories of subjects and not their imaginative capabilities, such analysis was not relevant.

Finally, there was no evidence that children with autism were more prone to perseveration or repetition than controls, suggesting that some claims of executive dysfunction theory of autism may not be specific to autism, or pervasive.

6.3: Summary and Conclusions from Experiments 4 and 5

The results of the Chessboard experiment and the Complex Pictures experiment lend support to the suggestion that children with autism are comparable to clinical matched controls in their capacity for using veridical imagery. They do not perform differently to clinical controls either in the amount that they can recall from visual memory, or the nature of those recollections. These findings suggest that the neurocognitive processes involved in generating and utilising veridical imagery may be intact in children with autism, and that these processes may differ from those required to "imagine" non-veridical things. However, both Experiments 4 and 5 may be argued to be passable without using imagery, but by using propositional memory or rules. The performance by some clinical subjects was very poor - at floor level - and these results question the ability of these experiments to claim either to have tapped veridical imagery, or to demonstrate intact performance in clinical groups.

Nevertheless the present results add to previous research which suggests that children with autism can utilise *veridical* mental imagery (e.g., Shah, 1988), and suggest that it is likely a general lack of imagery cannot explain the results from the Counterfactual Reasoning experiment (Experiment 3). The next possibility that was necessary to explore is that children with autism may have a specific deficit in imagery for non-veridical things.

CHAPTER SEVEN

Three Experiments Exploring Non-Veridical Imagery and Creative Imagination in Autism.

As was clear from the literature review in Chapter 5 there has been a great deal of research exploring mental imagery for absent, real things (e.g., see Tippett, 1992, for a review) - that is, veridical imagery of the kind explored in the previous experimental chapter. The widely accepted view at present is that the cognitive processes that are required for normal perception and vision are also involved in mental imagery, although not necessarily performing in an identical fashion (Kosslyn, 1994; Farah, 1988). However, there is little, if any, research into the cognitive processes involved in the generation and manipulation of mental images of absent and *unreal* things (e.g., the generation of a mental image of a green dog with five legs). Kosslyn (1994, Chapter 9) briefly discusses the fact that imagery can be used to combine objects in novel ways and to visualise novel patterns, but to date there is little experimental evidence on this. It is assumed that Kosslyn's (1994) hypothesis (that the cognitive processes needed for direct perceptual analysis in the visual system are the same processes that are involved in visual mental imagery) also encompasses mental images for *unreal* things.

The experiments reported here were designed to explore: (1) if children with autism have a deficit in the generation and/or manipulation of non-veridical imagery, but not of veridical imagery, and thus (2) whether representation of imagined but *real* things, and representation of imagined but *unreal* things depend on the same, or different, cognitive processes.

Imagination often involves the ability to image non-veridical objects and situations. For example, in pretence one may imagine being pursued by a monster from Mars; and creative imagination may require the mental imaging of previously non-veridical objects, thus allowing the invention of new tools, new artwork, and so-on. As has been reported in Chapter 1 and Chapter 5, much research has been conducted into the social and communication difficulties in autism (see Baron-Cohen, 1988) but there has so far been little exploration of imaginative abilities - that is, the ability to entertain non-veridical representations - in autism per se. Imagination in autism has, however, been examined indirectly - for example, the frequently reported finding of a deficit in production of pretend play by children with autism (e.g., Wing, Gould, Yeates, & Brierly, 1977; Ungerer & Sigman, 1981; Baron-Cohen, 1987). However, apart from such studies of pretend play, there has been almost no study of imagination in autism. Chapter 6 reported on how perceptual *veridical* mental imagery has been studied in autism, using Shepard & Meltzer type mental rotation tasks (Shah, 1988). This involves the subject manipulating an existing perceptual image, with the test item visible. This is manipulation of visual imagery of current, real, objects, and children with autism perform normally on this. They can also pass object-permanence tasks, by searching for an object where it was last put, implying that they can utilise visual imagery of *absent* (but real) objects (Sigman, 1987), and the findings from Chapter 6 suggest that children with autism also may not have a deficit with other forms of veridical imagery such as is involved in visual memory.

In contrast, it is hypothesised that when the subject has to visualise things that are not present and do not even "exist" (except in the subject's mind) this may involve a different cognitive and neural mechanism, and this may be selectively impaired in autism. Imagination at this last level may involve the ability to adapt and/or combine existing concepts to create new and non-empirical ones (Richardson, 1969).

The present experiments aimed to test this prediction by studying the production of drawings of imaginary entities: real and unreal. Tasks requiring subjects to produce drawings of objects arguably also require the subject to entertain a mental image of that object, and thus drawing tasks have been used to explore mental imagery in patients who have suffered brain damage (e.g., Beyn & Knyazeva, 1962; Levine, Warach, & Farah, 1985) as well as in normal development (see e.g., Thomas & Silk, 1990). Drawing in autism has been explored in the past to see if children with autism (including those who do not exhibit a precocious drawing talent) follow the same pattern of development as normal children in their attempts to represent what they see before them. By and large, they do (Charman & Baron-Cohen, 1993), and they also show similar strategies in the production of a variety of different drawings of their choice (Lewis & Boucher, 1991). However, whilst these earlier studies explored the child's ability to draw empirical, *real-world* concepts, as far as is known there has been no previous attempt to examine the production of drawings by children with autism of impossible or *unreal* things.

7.1: Experiment 6 - Drawings Task: "Real" versus "Impossible" Things.

This experiment was based on Annette Karmiloff-Smith's (1989) elegant study, where normally developing children (ranging from 4 years to 11 years) were first asked to draw a house and a man, and then asked to draw a *house that does not exist,* and a *man that does not exist.* Karmiloff-Smith found that when given the latter task, the younger children (4 - 6 year olds) changed their representations (by deletion of elements, and changes in size and shape of elements and of the whole), whilst the older children (8 - 10 year olds) went even further in introducing changes to their representations (they changed the position and orientation of elements, and added elements from other conceptual categories). For example, the younger children would draw a man with one leg, or a giant. The older children would draw a man with two heads and fifty fingers!

The present study was not concerned so much with the *types* of representational change, but rather with whether children with autism were capable of introducing these changes *at all,* compared to matched controls. It was predicted that the children with autism would be unable to represent "impossible" (unreal) houses and men, compared to matched controls.

7.1.i: Method

Subjects - Subjects were as reported in Chapter 2, subjects for experiments 4 to 8, (see Table 2:2).

Design and Procedure - All subjects were seen individually, in a quiet room in their school. The experiment involved a drawings task with two conditions ('house' and 'man'), plus an additional set of control questions. The order of conditions was counterbalanced across subjects, with half the subjects receiving the House Condition first, and half receiving the Man Condition first. A Control Condition was given after both the two Experimental Conditions had been completed by the subject. The two Experimental Conditions were administered on separate occasions, at least two days apart, with the Control Condition being administered at the end of the second session. Within each of the Experimental Conditions, the subject was first asked to draw the real object, and then asked to draw an unreal version of it. This fixed order was necessary because piloting showed that young normal children needed a warm-up period of drawing familiar, concrete objects.

Pretest - The experimenter presented the subject with some paper and a felt-tip pen, and asked the subject to copy some geometrical shapes. (Geometric shapes were chosen because children with autism often show a strong interest in geometric shapes).Two-dimensional drawings of the shapes were placed in front of the subject for him/her to copy. These comprised a square, a triangle, a circle, and a rhombus. There was no time limit placed upon the subject. This Pretest was to ensure that he/she was able to control the pen adequately, and draw at an age-appropriate level. If the Pretest was performed successfully, the experimenter then asked the subject if he/she would draw her a picture of a house/man.

Experimental Conditions: (1) House Condition - The subject was asked to draw a picture of a house. When the subject had completed the drawing (there was no time restriction) the experimenter said, "Well done. That's a lovely picture of a house. May I keep this picture?" The picture was put aside for later analysis. The experimenter then asked the subject to draw another picture of a house, but this time to draw a house that "..does not exist. An impossible house." (Other similar phrases were used as appropriate if the subject did not appear to understand the instruction, (e.g., "..a house that is not real", although the majority of the subjects responded to the original instructions). This second picture was also praised, and again the experimenter asked to keep the picture, regardless of whether the subject had successfully drawn an "impossible" house. The pictures were analysed at a later date.

(2) Man Condition - This was presented on a separate occasion to the House Condition. The subject was asked to draw a picture of a man. When the subject had completed the drawing (with no time restriction) the experimenter said, "Well done. That's a lovely picture of a man. May I keep this picture?" The picture was put aside for later analysis. The experimenter then asked the subject to draw another picture of a man, but this time to draw a man that "...does not exist. An impossible man." (Again, further prompts were supplied if the child did not respond to the original instruction). This picture was also praised, and the experimenter again asked to keep the picture, which was also put aside for later analysis.

Control Condition - The Control Condition was presented after the second Experimental Condition, and consisted of a series of five drawings of pairs of items (cows, women, balls, apples, and elephants). Items in each pair were identical except for one of them having an element that made it "impossible" or "unreal" (see Appendix 12). The subject was asked to point to "the (x) that does not exist. An impossible (x)." The instructions were phrased like this so as to be identical to the task instructions in each of the conditions. The subjects response to each of the pairs was recorded. This Control Condition was to check if subjects who failed to draw an impossible house/man in the Experimental Conditions did so because they did not understand the meaning of the terms "impossible" or "does not exist", for example. The Control Condition was presented as a post-test, so that the subjects could not use it as an aid to performance in the Experimental Conditions.

Scoring - In scoring the Experimental Conditions, analysis of the drawings produced by the subjects employed the same criteria as used by Karmiloff-Smith (1989). That is, in determining whether a drawing was an "impossible" house/man, the following criteria had to be met: (1) changes had to be made to the representation of a house/man which enabled the drawing to retain "houselike" or "manlike" characteristics, whilst also incorporating elements that do not normally belong in an accurate representation of a real house/man, or whilst deleting elements that should be present. (2) These changes could include: changing the shape and size of elements; changing the shape of the whole; deletion of elements; insertion of new elements; changing position and/or orientation; insertion of elements from other conceptual categories; and other changes (such as conventionalised forms, like mermaids). It should be noted that changing size of the whole alone was not counted as an impossible change - this strict interpretation was to avoid falsely classifying items as

"Giants", for example, when they were simply "real" people drawn larger than the child's first drawing.

For a subject to draw a "real" house/man, he/she had to produce a drawing that included the essential features and characteristics of househood/manhood (e.g., rectangular in shape, with a door, windows, roof; etc., and for a man, to have a head, two eyes, one mouth, one nose, two arms, two legs, etc.). Two independent judges (blind to the hypotheses being tested and to the diagnosis of each child) rated the children's drawings using the above criteria. Inter-rater agreement was perfect (100%) for both experimental conditions.

7.1.ii: Results

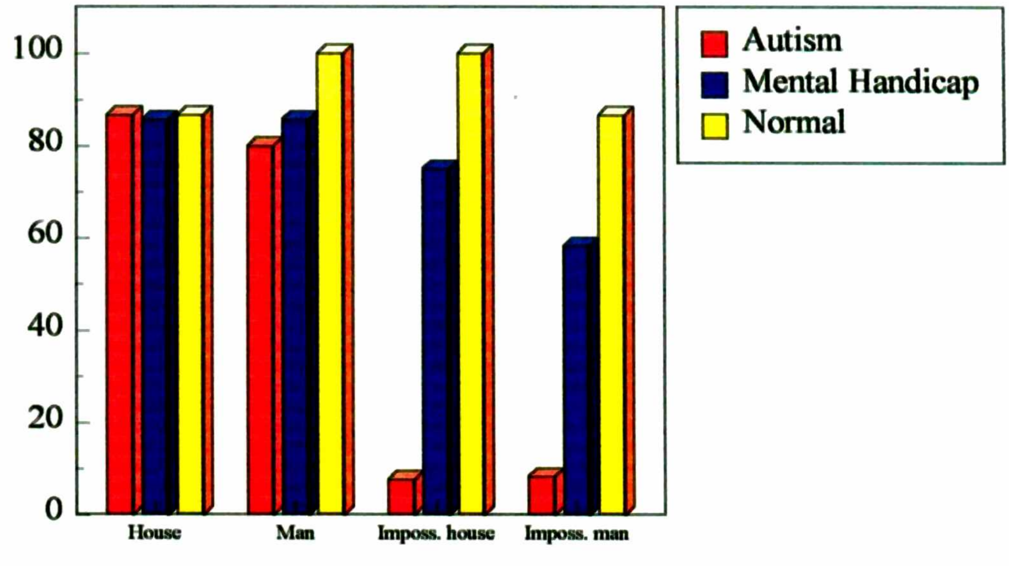
All subjects passed the Pretest by copying the geometric forms. Thus all subjects were included in the Experiment.

Analysis of Drawings of Real things - Analyses showed that there were no significant differences between the number of children in each group producing a "real" house (3-way Chi-Square = 0.0039, $p>0.995$). The analysis of drawings of "real" men showed a significant difference between the subjects with autism and the normally developing children (Autism x Normal, Chi-Square = 3.34, $p<0.05$), but not between the two clinical groups (Autism x Mental Handicap, Chi-Square = 0.17, $p>0.75$), suggesting that the results were due to more of the normally developing children producing drawings of men, and *not* because the children with autism had any specific problem with representations of real men. In fact, the normally developing children had a 100% success rate in drawing men, whereas the clinical groups were 80% successful (Autism), and 85.7% successful (Mental Handicap). The difference between the subjects with mental handicap and the normally developing children did not reach significance (Mental Handicap x Normal, Chi-Square = 2.28, $p<0.1$).

<u>Analysis of Drawings of Impossible (or Unreal) things</u> - The analyses of the drawings of "impossible" things showed that significantly fewer children with autism produced drawings of an impossible house than either the children with mental handicap (Autism x Mental Handicap, Chi-Square = 11.78, $p<0.001$), or the normal controls (Autism x Normal, Chi-Square = 22.28, $p<0.001$). The same was true of their attempts at drawing an impossible man (Autism x Mental Handicap, Chi-Square = 6.75, $p<0.01$; Autism x Normal, Chi-Square = 16.36, $p<0.001$). However, neither of the two control groups differed in their drawings of impossible men (Mental Handicap x Normal, Chi-Square = 2.79, $p>0.1$), although significantly fewer children with mental handicap produced drawings of impossible houses than the normal children (Mental Handicap x Normal, Chi-Square = 3.69, $p<0.05$). Examples of the drawings produced by each group are in Appendix 13. Figure 7.1 shows the magnitude of the difference in performance between drawing "real" and "impossible" things for the children with autism compared to the two control groups: only 7.7% of the sample with autism successfully drew an impossible house, and 8.3% an impossible man, compared to 75% and 58.3% respectively for the group with mental handicap, and 100% and 86.7% respectively for the normal children.

Fig. 7.1: Drawings Task - Real vs. Impossible

Percent of Ss successfully passing each condition.



Control Condition - The differences that were observed between the subject groups in their attempts to draw impossible houses/men were not due to the subjects with autism failing to understand the meaning of "impossible" or "an x that does not exist", as the results of the Control Condition showed: 93.3% of the subjects with autism passed 4 or 5 of the five control questions, compared to 78.6% of the subjects with mental handicap, and 100% of the normally developing children. There were no significant differences between the subjects with autism and the two control groups (Autism x Mental Handicap, Chi-Square = 0.35, $p>0.75$; Autism x Normal, Chi-Square = 2.14, $p>0.25$), although the difference between the children with mental handicap and the normally developing children just reached significance (Mental Handicap x Normal, Chi-Square = 3.8, $p<0.05$).

A further analysis was conducted to test if the children with autism were at a mental-age (MA) appropriate level in their drawing of men, compared to controls, in order to investigate if their failure in the Experimental Condition could be due to an inferior ability draw people. Using the scoring methods employed in the Goodenough-Harris Draw-A-Man Test (1963), and basing the analysis on verbal MA, 76.9% of the children with autism were at or above the mean for their MA level, compared to 62.5% of normal children, and 30.77% of the children with mental handicap. Thus, poor performance on the "impossible" conditions of the Experiment by subjects with autism was not due to differences in drawing ability relative to controls.

7.1.iii: Discussion of Experiment 6

The results of this Experiment suggest that there is indeed an abnormality in the ability of children with autism to produce "impossible" or unreal representations. The finding thus also lends support to the notion that representation of unreal objects may involve different or additional neuro-cognitive systems, compared to representation of real objects. This is consistent with Leslie's (1987) proposal that in the normal cognitive system there may be two types of representation, and that in order to pretend or engage in imaginative behaviour, a child has to not only be able to create a *primary* (or veridical) representation of what he/she perceives, but also a *decoupled* representation which can be manipulated and changed, independent of reality. Leslie suggested that children with autism are intact in their capacity to form primary representations, but cannot spontaneously produce pretend play because of abnormalities in forming decoupled representations. In Leslie's terms, then, the subjects with autism may have been unable to produce drawings of "impossible" entities because to do so would require an ability to produce decoupled representations, so as to be able to introduce changes in the primary representation without disrupting the original concept (or causing what Leslie (1987) calls "representational abuse"). Since children with autism had no problems in producing drawings of "real" entities, it is clear that they can create primary representations, and this is in line with other studies, (e.g., Ungerer & Sigman, 1981; Charman & Baron-Cohen, 1993).

However, the present results can also be interpreted as support for the executive dysfunction theory of autism described in Chapter 1. The executive dysfunction theory suggests that in autism there is a specific deficit in performing functions such as planning, flexible switching between response behaviours, inhibiting inappropriate responses, and spontaneously generating varied outputs, for example. It could be argued that the children with autism were unable to produce drawings of unreal things because executive dysfunction prevented them from inhibiting production of drawings of the real things. This explanation is markedly different to Leslie's (1987,1994) hypothesis since the latter suggests that pretence by children with autism cannot be improved because the problem lies in an impaired cognitive mechanism involved in imagination. In contrast, the executive dysfunction hypothesis predicts that performance by children with autism *can* be improved if the executive demands of the task are reduced. In order to test these two alternative theories against each other, a further experiment was conducted. Experiment 7 assessed both spontaneous and instructed production of drawings, of both real and unreal items. In this way it was possible to test whether children with autism *could* produce representations of unreal entities under conditions where the experimenter (rather than the child) took executive control, or whether they would still show a deficit in the domain of imagining unreal entities compared to matched controls.

7.2: Experiment 7 - Drawings Task: Spontaneous versus Instructed, "Real" versus "Unreal".

7.2.i: Method

Subjects - Subjects were again as reported in Chapter 2, see Table 2:2

Design and Procedure - This Experiment involved a further drawing task, with 3 successive conditions.

Condition 1 - Spontaneous Drawing - In the first condition, the subject was given paper and a felt-tip pen and asked "Draw me a picture of something frightening. Something really scary!" This condition therefore explored their ability to spontaneously produce a drawing of an exciting subject, to assess if they spontaneously drew something real or something unreal.

Condition 2 - Instructed Drawing of Something Real - In the second condition, the subject was *instructed* by the experimenter to draw something real, which was frightening (such as a spider or a snake). The experimenter checked that the subject agreed the chosen example was indeed frightening, and then told the subject what to draw, and specifically how to draw it. Thus, for example, the experimenter would say, "Can you draw a spider" and would prompt, e.g., "Draw a round body. O.K. Now draw eight legs on the body - one, two,......eight." This condition was therefore a further check that the subject could follow the experimenter's instructions for drawing a real object.

Condition 3 - Instructed Drawing of Something Unreal - In the third condition, the subject was *instructed* by the experimenter to draw something unreal or impossible, which was frightening (e.g., a two-headed monster). Again the experimenter told the subject what to draw, and specifically how to draw it. For example, the experimenter would say, "Can you draw a monster with two heads?" and would prompt, e.g., "Now draw some big teeth", "Now draw another monster head on the body", "Now draw two horns", and so-on. This condition therefore assessed the subjects abilities to produce drawings of unreal things under specific instruction. This was to test if a lack of such drawings in Condition 1 (above), and in Experiment 6, was due to a problem in executive control, or in processing representations of unreal things.

All pictures produced by the subjects were kept for later analysis. Each subject received all three conditions during a single session, in the fixed order above. The order was necessarily fixed so as to avoid the instructed condition (2) influencing the spontaneous condition (1), or the instructed imaginary condition (3) influencing the instructed real condition (2).

Scoring - Two independent judges (again, blind to hypotheses and diagnoses) categorised the children's drawings, following the methods outlined below. Drawings in Condition 1 were rated as "real" if they depicted a factual, real-world object (such as a rollercoaster, or a crocodile), and "unreal" if they depicted something that does not exist (such as a ghost, or a monster). The subjects were asked for verbal clarification of what they had drawn, to ensure that no drawings were misclassified. Drawings in Conditions 2 and 3 were scored as a "Pass" if the subject successfully drew the object that the experimenter had instructed, and scored as a "Fail" if the subject drew nothing at all, or drew something other than the item instructed. As before, the subjects were asked to clarify what they had drawn, so that in cases where a subject may have been attempting to do as instructed but there was some ambiguity in the drawing (e.g., only one horn on the monster's head, when asked to draw two) the experimenter was able to note whether the drawing was a genuine attempt to follow the instruction. However, if a subject attempted to draw what had been requested, but drew a real-world object (e.g., drew a "real" man when asked to draw a two-headed hairy monster), the drawing was scored as a "Fail". Inter-judge agreement was again very high: 100% for Conditions 1 and 2, and 94% for Condition 3.

7.2.ii: Results

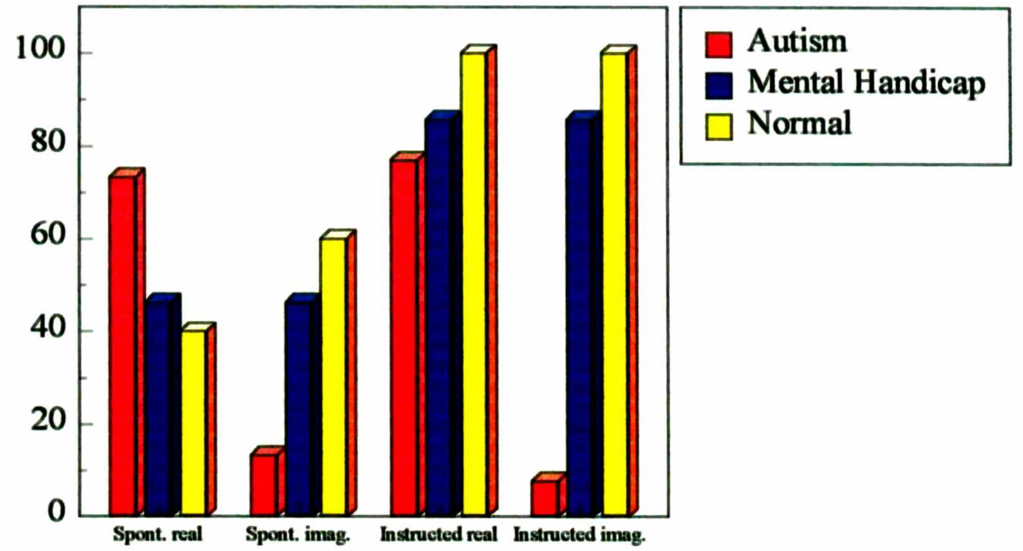
In Condition 1, where the subjects were simply asked to draw something they thought was frightening, 60% of the normally developing subjects and 46.2% of the children with mental handicap spontaneously drew something imaginary (e.g., a monster), whereas only 13.3% of the children with autism did so. Among the children with autism 73.3% spontaneously drew something real (e.g., a snake). This difference was significant (Autism x Mental Handicap, Chi-Square = 3.17, $p<0.05$; Autism x Normal, Chi-Square = 7.04, $p<0.005$). In Condition 2, where the subjects were *instructed* to draw a particular "real" scary thing (e.g., a spider), and told how to draw it, there were no significant differences between the three groups. 76.9% of the subjects with autism, 85.7% of the children with mental handicap, and 100% of the normally developing children were able to draw the requested object under instruction; (Autism x Mental Handicap x Normal, 3-way Chi-Square = 1.76, $p>0.75$).

However, in Condition 3, where subjects were *instructed* to draw an imaginary or impossible thing (e.g., a hairy two-headed monster), again being told what to draw and how to draw it, the children with autism were significantly worse than both control groups. 100% of the normally developing controls drew an imaginary/impossible thing under instruction, and 85.7% of the children with mental handicap also did, whereas only 7.7% of the subjects with autism did. (Autism x Mental Handicap, Chi-Square = 10.07, $p<0.001$; Autism x Normal, Chi-Square = 15.03, $p<0.001$; See Fig.7.2.)

It was noted that in Condition 3, seven children with autism drew nothing at all in response to the instruction, whilst six drew a normal person (confirmed by experimenter questioning) whilst apparently attempting to draw a two-headed monster (for example, three of these subjects drew a second head, and then drew a second complete body with it - resulting in a drawing of two *real* people), or drew an unrelated but real object. Six of these subjects spontaneously stated that they *could not* draw what the experimenter had requested (examples of drawings produced by each group are shown in Appendix 14).

Fig. 7.2: Drawings Task - Spontaneous vs. Instructed

Percent of Ss successfully passing each condition



7.2.iii: Discussion of Experiment 7

The results of Experiment 7 suggest that even when executive control passes from the child to the experimenter, children with autism cannot produce drawings of unreal entities. The subjects with autism were able to follow the experimenter's instructions as well as those in the two control groups (as demonstrated in Condition 2), so the poor performance in Condition 3 could not have been due to an inability to act under instruction. Following the earlier argument that drawing tasks require imagery (e.g., Beyn & Knyazeva, 1962) this leaves as a more likely explanation the possibility that children with autism have a deficit in the processing of images of unreal objects. Since both the spontaneous (Condition 1) and the instructed (Condition 2) responses of the subjects with autism were reality-based, it may be that this is the only way in which these subjects are capable of thinking. Children with autism may have a deficit in the ability to represent concepts in anything other than "factual" format. They appear unable to manipulate concepts to create non-veridical or imaginary/impossible ideas.

However, the executive dysfunction theorist has a further possible repost: perhaps children with autism performed poorly in both Experiments 6 and 7 because of a *generativity* deficit. That is, in the spontaneous generation of varied ideas or behaviours. Generativity is what the central executive is held to allow (Shallice, 1988). Jarrold, Boucher & Smith (submitted) suggest that children with autism can engage in instructed pretence, but that they are impaired in producing spontaneous pretence because of generativity problems. In the same way, it could be suggested that the children with autism in the present studies were unable to represent unreal objects because they have a deficit in the ability to generate novel ideas. The generativity hypothesis seems plausible because a number of previous studies suggest there may be impairments in this domain (Rumsey & Hamburger, 1987; Lewis & Boucher,1991; Boucher, 1988; Hughes, Russell & Robbins, 1994), although the finding that children with autism could not produce unreal drawings, even when instructed, questions such a claim. Nevertheless, to test this idea further Experiment 3 was conducted to assess if children with autism are impaired, relative to controls, in their ability to generate novel ideas, even when the ideas are of real objects. The standard measures of these are the Verbal Fluency Task (e.g., Benton & Hamsher, 1976; Milner, 1964; Perret, 1974) and the Functions of a Brick Task.(e.g., see Lezak, 1983). The Verbal Fluency Task employed in Experiment 8 tested phonemic (or graphemic) Verbal Fluency, rather than semantic Verbal Fluency (e.g., Boucher, 1988). Phonemic Verbal Fluency is impaired in patients with damage to the left frontal cortex (e.g., Milner, 1964; Benton, 1968; Perret, 1974), whilst semantic Verbal Fluency is impaired in patients with severe memory disorders (e.g., Talland, 1965) and patients with various left hemisphere lesions (e.g., Newcombe, 1969).

7.3: Experiment 8 - Assessing Generativity

7.3.i: Method

Subjects - Subjects were again as reported in Chapter 2, see Table 2:2

Design and Procedure - This Experiment had 2 conditions - Functions of a Brick, and Verbal Fluency. The two conditions were presented in counterbalanced order across subjects and were presented on separate occasions, with at least two days between each condition.

Functions of a Brick Condition - The subject was presented with a toy "brick" and asked "What can you do with this brick? What could you use it for?". Their responses were tape-recorded for later analysis, and a time limit of 2 minutes was allowed. During the 2 minute period, the experimenter encouraged and prompted the subject saying, "That's a good idea. Now, what else could you use the brick for? Tell me as many things as you can that you could do with the brick."

Verbal Fluency Condition - The experimenter asked the subject, "Tell me as many different words as you can think of that begin with a F sound (A sound, S sound). What starts with a F?". The letters were spoken phonemically so that the task would be easy enough for children who did not know their alphabet or who were poor readers. Again two minutes were allowed for each letter, and the experimenter encouraged and prompted the subjects saying, "That's a good word. What else starts with a F (A,S)?". All responses were praised, though if the words chosen did not actually start with the required letter these were not counted and the experimenter reminded the subject that the word should start with the relevant sound. Once again, the subject's responses were tape-recorded for later analysis.

7.3.ii: Results

Both the Functions of a Brick and the Verbal Fluency Conditions produced a low level of output from all three groups, a maximum number of 6 items being generated in either condition (see Appendix 15). Table 7.1 shows the mean number of items produced by each group in each Condition. It is apparent that there may be a floor effect with these results, which may have been due to the relatively low verbal mental ages of the subjects. However, it is clear that there is no difference between the clinical groups, as analyses confirmed.

Table 7.1: Mean Number of Items Produced

SUBJECTS		VERBAL FLUENCY	BRICK TASK
Autism	Mean	1.2	2.47
	Standard Deviation	1.17	1.45
	Range	0 - 5	0 - 5
Mental Handicap	Mean	1.36	2.57
	Standard Deviation	0.97	1.16
	Range	0 - 4	1 - 5
Normal	Mean	2.79	3.73
	Standard Deviation	1.62	1.48
	Range	0 - 6	1 - 6

Functions of a Brick Condition - For the Functions of a Brick condition, a one-way ANOVA showed a significant difference between the groups ($F(2,41) = 3.68$ $p<0.05$). A Post hoc Scheffe comparison showed that this was because the subjects with autism generated significantly fewer ideas than the normally developing controls (Autism x Normal, $p<0.01$), but not than the subjects with mental handicap (Autism x Mental Handicap, $p>0.05$). On average, both clinical groups generated less than 3 ideas in the allotted time, 80% of the children with autism generating 0-3 ideas ($x = 2.47$) and 78.6% of the children with mental handicap generating 0-3 ideas ($x = 2.57$). The normally developing children, on the other hand, generated on average more than 3 ideas, with only 33.3% of that group generating 0-3. (The mean for the normal group was 3.73 ideas.)

When the kinds of ideas that the subjects generated were examined, it was found that 71.4% of the children with mental handicap, and 66.7% of the normal 4-5 year olds, generated at least 1 abstract or pretend idea as to what the brick could be used for. For example, after giving such examples as "Building a house", or "Put it in a wall", one child suggested "Pretend it's a bed for dolly", and "Use it to stand (cassette) tapes on - a tape stand". Considering that most children with mental handicap only generated 2-3 ideas in total, such pretend ideas constitute a high proportion of their answers. In contrast, 86.7% of the subjects with autism did not generate any abstract or pretend ideas at all. This difference was highly significant (Autism x Mental Handicap, Chi-Square = 8.48, $p<0.005$; Autism x Normal, Chi-Square = 8.9, $p<0.005$). Thus, although the total number of new and varied ideas generated by the subjects with autism did not differ from the clinical control group, the content of those ideas did.

Verbal Fluency Condition - For the Verbal Fluency condition there was a significant difference between the three groups (One-way ANOVA, $F(2,40) = 5.24$, $p<0.01$). A Post-hoc Scheffe test showed that the children with autism did not differ in the number of items generated from the children with mental handicap (Autism x Mental Handicap, $p>0.05$). The children with autism generated a mean of 1.2 words, and the children with mental handicap generated a mean of 1.36 words. The normally developing children performed significantly better than both clinical groups (Normal x Mental Handicap, $p<0.01$; Normal x Autism, $p<0.01$), with these children generating a mean of 2.79 correct words.

7.3.iii: Discussion of Experiment 8

Experiment 8 showed that on both the Verbal Fluency task and the Function of a Brick task, all three groups performed at or near floor level. The low number of items produced by the clinical groups in both the Brick condition and the Verbal Fluency condition may reflect their mental handicap, and it is possible that a greater difference would have emerged if the subjects had been of a higher general ability. The two tasks were clearly too difficult for the subjects involved.

The poor performance by the subjects with autism in representing unreal objects in Experiments 6 and 7 could still not have been due to deficits in generativity, since these subjects were able to produce varied outputs under instruction in Experiment 7 - an ability which requires some generativity - but Experiment 8 cannot strengthen that claim in itself. However, although generativity in autism may be poor compared to normal children, it does not appear from results to be an autism-specific deficit. Previous studies of generativity in autism have reported a deficit compared to normal subjects. For example, Rumsey and Hamburger (1987) found that high-functioning adults with autism performed significantly less well than matched normal controls in a variety of frontal tasks, including Word Fluency. Boucher (1988) also found a deficit in performance with high-functioning autistic children, compared to matched normal controls, in their ability to generate miscellaneous words without semantic category cues. However, both of theses studies compared the subjects with autism to only MA-matched *normal* subjects. Critically, there were no clinical subjects used as controls. Thus, one possible explanation for the present results is that this aspect of executive function is a product of mental handicap, exhibited in a number of clinical syndromes, and is independent of autism. The results of Experiment 8 also lend potential support to the argument that children with autism have a specific deficit in processing representations of unreal objects and concepts, since they generated significantly fewer abstract/pretend ideas than the two control groups, whilst still performing equally in the overall number of varied ideas generated, compared to the children with severe learning difficulties.

7.4: Summary and Discussion of Experiments 6 to 8

The three experiments reported here suggest that children with autism have a deficit in the representation of unreal objects: (1) Experiment 6 found that children with autism showed a deficit in performance, compared to both clinical and normal control groups, in their ability to draw "impossible" houses and men. (2) Experiment 7 found that this deficit in performance was not likely to be due to an executive dysfunction, since they were unable to produce drawings of "impossible" things even when executive control had passed to the experimenter. Finally, (3) Experiment 8 suggests that the deficit in performance may not be due to a generativity deficit, since they were no different to clinical controls in the ability to generate words or ideas of real objects. Note also that the deficit in Experiment 6 could not have been simply due to perseveration (or a failure of inhibition), since when asked to draw different *real* objects, they were capable of changing their drawings from one trial to the next (see Experiment 7).

The evidence from these three experiments thus points to an abnormality in the ability to transform veridical representations into non-veridical ones, both spontaneously and under instruction. This may explain not only the lack of imaginative drawings, but also the lack of spontaneous pretence, produced by children with autism: In order to pretend one has to be able to override one's knowledge of reality, to create an unreal idea, by ascribing to an object or agent properties that are not present in "reality".

In Chapter 5, some evidence was described of children with autism demonstrating pretend play. Jarrold, Boucher & Smith (submitted) suggested that children with autism *can* produce pretence if they are instructed to do so, and this has also been found by others (Lewis & Boucher, 1988; Charman & Baron-Cohen, in press). For example, Jarrold et al found that under instruction children with autism will use an item such as a length of dowel appropriately as a "pretend" toothbrush. However, in this example, it is not clear if they are doing this because they are representing an unreal object, or simply because they have been requested to perform a certain action and the length of dowel is the only item available that resembles a toothbrush. Baron-Cohen (1989b) called this "intelligent guessing". To mimic a well-known routine does not necessarily require representing an unreal object or necessarily require an understanding of pretence; it simply shows that the subject is able to use a real object, or the nearest available substitute. The existence of instructed pretend play in autism is therefore not incompatible with the findings from the present study in which subjects with autism were unable to represent unreal things.

Returning to the second issue which these experiments set out to explore - might representation of real and unreal objects involve different neurocognitive mechanisms? The results from the 3 experiments reported in this chapter strongly suggest that in autism these two kinds of representation dissociate from one another, and in this sense they lend support to Leslie's (1987) contention that children with autism can produce primary (veridical) representations, but cannot produce representations of unreal (non-veridical) things. Why might such a deficit arise? One possibility is that representing an unreal object involves "bolting together" or fusing two representations of real objects. For example, in producing the representation of a flying pig one needs to represent a real pig (without wings) and a real bird (with wings), fuse aspects of these, to create the novel non-veridical representation. If the deficit in autism was simply an inability to fuse two primary representations together, then they should be unable to perform Finke, Pinker & Farah's (1989) task of imagining what is created when one joins a J with a D on its side (Answer: an umbrella). This is a possibility that needs to be explored in the future.

An alternative account relates the deficit in representing unreal objects to the deficits in employing a theory of mind (Baron-Cohen, Leslie & Frith, 1985; see Baron-Cohen, Tager-Flusberg & Cohen, 1993 for a review). On this account, representing an unreal object necessarily requires pretending, or representing that you (the agent) are holding a pretend *attitude* (or *mental state*) towards an object. Leslie's (1991, 1994) suggestion is that representing attitudes is the function of ToMM (or the Theory of Mind Mechanism), and it is this which is impaired in autism. Testing between these two accounts is a priority for further research in this area.

CHAPTER EIGHT

Reasoning, Imagery, and Imagination in Autism - Discussion

Before summarising the findings from the experiments reported in this thesis, a reminder of the original aims may be useful: The aims of this thesis were: (i) To explore general reasoning abilities by children with autism in tasks which are performed successfully by normal children at around the same time as traditional theory of mind tasks, but which do not focus on mental state understanding; (ii) To explore imagery in children with autism; and (iii) To further explore imagination in children with autism.

8.1: Summary of Findings, and Their Relation to Theory and Literature

Since the thesis is divided into the study of reasoning on the one hand, and imagery and imagination on the other, these aspects will be summarised separately for the sake of simplicity. It should be emphasised that this by no means suggests any real segregation between the two areas. As has been clearly seen from the literature, reasoning theories include hypotheses about mental models (i.e., imagery), and some imagery tasks require degrees of reasoning, demonstrating a degree of interrelatedness. The division is only made for clarity of presentation, and where appropriate the relations between the two areas will be addressed.

8.1.i: Reasoning Experiments

Experiments 1 and 2: The Transitive Inference Experiment and Analogical Reasoning Experiment - These experiments explored the capacity for logical reasoning in children with autism compared to matched clinical and normal controls. Results suggested that children with autism were comparable to clinical controls in their ability to pass tasks of analogical and inferential reasoning, and thus failure in traditional theory of mind tasks cannot be due to a general inability to deal with the levels of reasoning which such tasks require.

Experiment 3: The Counterfactual Syllogistic Reasoning Experiment - The results from this experiment support the earlier demonstrations of competent performance by children with autism in tasks of factual logical reasoning (reported in Experiments 1 and 2). In addition, in this experiment the subjects with autism demonstrate the ability to reason with information that runs counter-to-reality.

Relation of Findings to the Literature - The present findings provide evidence that both children with autism, and children with mental handicap (a population that also has not received much study of reasoning development) are both able to perform a variety of reasoning tasks. Until recently, these had only been demonstrated in normally developing children. Thus, the evidence suggests that these clinical groups are capable of performing at a mental-age appropriate level on simple tests of transitive inference, analogy, and syllogisms, although less well than normal children. These findings run counter to previous tests of problem-solving reported in Chapter 3, comparing subjects with autism and normal controls (e.g., Rumsey and Hamburger, 1987; Minshew et al., 1994). They also provide evidence to suggest that subjects with autism do not suffer from a *general* inflexibility of thought (e.g., Ozonoff, Pennington, and Rogers, 1991; Ozonoff et al., 1993) or from a total inability to make coherent sense of separate pieces of information (e.g., Frith, 1989; Frith and Happe, 1994). It may be that under certain conditions where it is beneficial to see scenes in terms of constituent parts (e.g., in the Embedded Figures task) children with autism are more proficient than normally developing children, but it would appear that they are no less able to combine elements and perceive things as a whole when the task demands they should.

The results from Experiments 1 to 3 lend support to the theory of mind hypothesis of autism, in that the subjects with autism were capable of performing the "non-mentalistic" reasoning tasks presented. This is not to say that the tasks did not require the use of some form of mental model (e.g., Johnson-Laird, 1987) - they may well have done. In line with other non-mentalistic representation tasks (such as false-photographs, which children with autism are able to pass, e.g., Leekam and Perner, 1991), the findings demonstrate that children with autism can form mental representations if they do not involve a mental state attribution. In other words, as long as it is not necessary to think about one's own or someone-elses intentions, beliefs, attitudes, and so-on, subjects with autism can utilise mental representations - and even metarepresentation, by Perner's (1993) definition.

However, reasoning may not only depend on mental models for successful performance. Other theorists argue in favour of propositional understanding in reasoning (e.g., Rips, 1989; Braine, 1978; Geis and Zwicky, 1971) and it cannot be ruled out that perhaps children with autism reason in a propositional, rule-based way. This suggestion does not diminish the significance of their performance on abstract reasoning tasks. It does, however, raise the possibility that the cognitive processes employed by subjects with autism may differ from those of normally developing and mentally handicapped children, - they may not involve mental representation in the form of "models". The results from the Verbal plus Imagery condition of Experiment 3 - the Counterfactual Syllogisms - supports this suggestion. Here the children with autism decreased in their performance, whilst the two control groups improved. If the children with autism were using a propositional strategy to solve the syllogisms, without "imagining" the situations described, they would be expected to perform better in the Verbal Only condition, and performance would be expected to worsen when they were instructed to create a mental image of the content of the syllogisms.

An alternative explanation is that the children with autism may have performed better in the Verbal Only condition because unlike the control groups they were not attempting to understand the experimenter's intentions. However, this argument does not seem to fully account for their worse performance in the Verbal plus Imagery condition. At best it can account for why the non-autistic subjects performed better in the Verbal plus Imagery condition (i.e., through clarification of the experimenter's intentions), but if the subjects with autism were simply following the instructions, this should have led to success regardless of what the experimenter might intend. The only explanation for the worsening of performance is that the children with autism had problems in *imaging* the syllogisms. They could process the counterfactuals in the Verbal Only condition, but were unable to process them when instructed to image them. This result might be taken as preliminary support for the simulation theory, since it suggests a deficit in imagery and imagination. This finding will be evaluated further later.

Future Directions - There is obviously a clear need to replicate the findings. This is especially important in Experiment 3, the Counterfactual Syllogism experiment, where the results are so striking. It would also be beneficial to unconfound experimenter intention and imagery in the Counterfactual Syllogism experiment, perhaps by giving more explicit details in the Verbal Only condition concerning intentions (about reality and fantasy) than were originally supplied. In this way if recognising intention is the problem, performance by children with autism should worsen in the Verbal Only condition comparable to the Verbal plus Imagery condition. If, however, imagery is the sole problem, results should remain the same.

In Experiment 2, the Analogy task, it would have been useful to note the presentation order of items, since anecdotally it appeared that children with autism were sometimes drawn to the first item which physically matched the test item, regardless of the causal change. If this task was re-run, this should be checked.

Although these results suggest reasoning ability in clinical groups relative to mental age, future work could explore reasoning in more detail. It would be of interest to see how children with autism perform with Cosmides-Style "Social Contract" tasks. Theory of mind would predict either no change in performance across social versus non-social Wason-style "If P then Q" tasks, since the social element would not assist subjects with autism, and these subjects might even perform worse with social problems - the reverse of normal performance.

Also, it was clear from the literature review (Chapter 3) that there are many different areas of reasoning in which normally developing children and adults have been tested, including inferential understanding, deduction, paralogical (knight/knave) problems, and so-on. Since reasoning in children with autism and children with mental handicap has barely been studied before, there are clearly many areas that are open to study. This thesis has demonstrated that contrary to some expectations these groups *can* reason, thus opening the way to further research of such cognitive processes.

8.1.ii: Imagery and Imagination Experiments

Veridical Imagery - Experiment 4 (Chessboard task) and Experiment 5 (Complex Pictures) - The two experiments on veridical imagery described in Chapter 6 presented data suggesting that veridical imagery may also be intact in children with autism. Both of these experiments arguably involved visual, and in the case of the Chessboard experiment, spatial memory processes. However, many subjects performed poorly, questioning the validity of the experiments, which had attempted to add to previous work in autism using tasks of mental rotation and veridical visual imagery (e.g., Shah, 1988; Hermelin, 1975) where the stimulus remains present during testing.

Non-Veridical Imagery and Imagination - Experiment 6 (Real versus Impossible Drawings) and Experiment 7 (Spontaneous versus Instructed Drawings) - Experiments 6 and 7 provide evidence that whilst children with autism are capable of veridical imagery, they are unable to utilise non-veridical imagery.

Experiment 8 - Generativity Tasks - Experiment 8 suffered from floor effects, with all 3 groups performing poorly. In the material which was produced, however, the children with autism were noted to produce few if any "pretend" ideas.

Relation of Findings to the Literature - As was the case with the reasoning experiments, the finding that the children with autism who performed well on the task do not preferentially recall specific details in Experiment 5, the Complex Pictures task, is surprising in the context of the weak central coherence hypothesis. If children with autism preferentially perceive parts rather than the whole, they should have recalled a greater number of specific details compared to controls, but this was not the case. Nor did the children with autism give more perseverative or repetitive responses in this task compared to controls, questioning the extent to which they suffer specific executive function deficits.

Furthermore, the comparable performance by children with autism and control groups on the veridical imagery tasks (Experiments 4 and 5) causes potential problems for

Currie's (1994; 1995) outline of simulation theory. Currie suggested that children with autism have a "deficient simulator", and that this not only explains deficits in theory of mind and planning, but also predicts deficits in mental imagery. (He claims imagery is the result of simulation of the visual system). This is apparently not the case - children with autism do not exhibit visual imagery deficits. However, a possible way of saving Currie's account is to argue that imagery is *not* simulation of the visual system. Rather, imagery may utilise parts of the visual system directly. It may be possible, therefore, that veridical imagery is intact in autism, whilst the "simulator" is not. This concession would, however, require Currie to reconsider his definition of "simulation", providing a definition which is less all-encompassing than his current hypothesis suggests. It could be argued that by thus reducing "simulation" to a level at which it only relates to simulating other people's mental states, or performing pretense and other "imaginative" activities, simulation collapses into theory of mind. This is similar to the arguments put forward by Leslie and German (1995), and suggests that perhaps simulation theory needs to re-define and clarify its position if it is to argue for a difference between theory of mind and mental simulation.

Future Directions - Turning to Experiment 4: does the Chessboard task necessarily require visual imagery? This question is similar to that made in relation to the reasoning experiments. It is a possibility that the Chessboard task could have been passed by utilising a form of propositional rule, such as "The draught was on the top left square, which was white", or "The draught was 3 squares in from the left, and six squares down", etc. This technique would simply require that the subject counts out

the relevant squares on the board in front of them, and places the draught appropriately. However, for those few subjects with autism who demonstrated superior performance, reproducing 3 draughts on a full-size board, this seems unlikely. Such a method would entail really rather complex rules. More likely, these subjects may have a savant ability in visual or spatial memory, in line with the suggestion that around 5% of people with autism are savants (e.g., Frith, 1989). Certainly, further testing of these subjects in the future to see exactly how far they are able to go with this task would be of interest. Are they able to reproduce large numbers of different coloured draughts on a full-size board with only a short time to view it?
The claim that imagery *is* necessarily being used cannot be made unequivocally for the remainder of the subjects, however. Even though later experiments support the conclusion that children with autism are capable of veridical imagery, the Chessboard task (Experiment 4) may not have been designed in the most appropriate way for testing visual imagery alone.

An interesting point relevant to normally developing children was made in the discussion of Experiment 5 (the Complex Pictures task): the normally developing children had a greater tendency to "invent" recollections from the pictures in the Story condition. This was not something which was explored in the present experiment, but could be of interest to study. It is unlikely that the children believed their invented recollections to be true so soon after seeing the original picture. More likely this response was due to the instruction to "Tell a story", something which encourages fantasy and imagination in normally developing children. It would however be of interest to explore their recollections after a longer time period. Would the children remember which elements were *really* presented in the pictures, and which were invented? Or would they, as Harris (1994) suggests, confuse real and fantasy information?

Considering the Generativity tasks, although Experiment 8 demonstrates comparable generativity performance between clinical groups in particular it was clear from the results that the subjects were performing close to floor levels. In order to test the strength of the claim that generativity cannot account for the earlier task differences it is important for future work to administer less verbal generativity tasks. Both of the tasks presented in Experiment 8, whilst being established generativity tests, were also very reliant upon verbal ability. Whilst attempts were made to facilitate performance by using phonetics rather than letters in the verbal-fluency task, this clearly did not reduce task demands to a level which was appropriate for children with a mental-age of around 4 years. The conclusion must be that the generativity tasks presented in this thesis were too advanced for the subject groups involved. Future research should allow for this.

Another important test for the future will be to explore whether the deficit exhibited by children with autism in Experiments 6 and 7 is limited to non-veridical or impossible things, or relates to anything *novel*. One way of testing this would be to use the Finke, Pinker, and Farah (1989) task requiring subjects to image, for example, a capital 'J' with a capital 'D' lying on top on its back - an image which forms an 'umbrella'. This would not only explore whether children with autism can construct images out of two separate representations which are effectively "bolted together", but also whether they can image a novel item which is made up of veridical things. Since experiments 6 and 7 only explored "impossible" things, such as monsters, two-headed men, impossible houses, and so-on, the results cannot demonstrate for certain whether any deficit in drawing such representations is due to their non-veridical nature, or due to the fact that the subjects are required to create a novel item.

A further aspect of this research which requires disentangling is the possibility that the deficit exhibited by the children with autism in representing non-veridical things might have been due to an inability to manipulate already learned, fixed *concepts*. However, it could be argued that manipulating concepts and mentally imaging non-veridical items are one and the same thing, or are at least closely related. Future research should attempt to clarify whether it is manipulation of concepts, rather than creation of non-veridical images, which is problematic for children with autism.

In Experiment 6, subjects were required to demonstrate understanding of the term "impossible" and the phrase "does not exist" by asking them to point to the appropriate picture in a pair. In retrospect, it would have been interesting to test whether children with autism were able to *copy* the impossible drawings used in the control condition after the drawings tasks had been completed. In this way one could test if they are unable to copy non-veridical representations as well as being unable to draw them under instruction. This is something else which should be explored in the future.

Another adaptation from Experiment 7 could also be explored. Can children with autism produce drawings of impossible things under instruction if each part of the drawing is concealed as they go along? In other words, if they cannot see what they are drawing, and are in effect only drawing separate "disembodied" parts, will they follow the instructions. The findings would have implications for the argument that children with autism are unable to bolt together different representations to form a non-veridical image.

Other possibilities for future research include testing whether children with autism can *describe* non-veridical things - is the deficit limited to visual imagery and representation, or does it extend to verbal performance? If the deficit is due to a central problem, then one would expect children with autism should also perform poorly on verbal tasks. Using the verbal modality should therefore not change the results.

Also, exploring understanding of fantasy in cartoons, films, and books by children with autism would be of interest. Do they assume that these are representations of reality? Since they were able to identify the "impossible pictures" in the control condition of Experiment 6, they may not think they are real. Why then do they not produce drawings of these characters when asked to draw something impossible?

Finally, it will be important to test between the imagery for unreal entities deficit, and the theory of mind deficit. The two positions may be closely related. However, the former position implies that manipulating mental representations is deficient, whereas the latter suggests a specific deficit relating to the ability to represent an *attitude*. The distinction between these two points is not clear-cut, and so future research should attempt to clarify and compare these positions.

8.2: Implications for Theories of Autism

The results from the experiments reported in this thesis provide new evidence concerning autism and imagination, something which had not been studied in great detail before, as well as autism and reasoning. They also raise questions in relation to the current theories of autism. Do children with autism really preferentially attend to specific details as is suggested by the central coherence theory? Do they in fact have a specific generativity deficit, or a tendency to perseverate, as is suggested by the executive dysfunction theory? The current evidence guards against a strong form of either of these theories. Nor do they seem to show an inability to use veridical mental imagery, as some simulation theorists propose.

More questions have been raised than answers have been proposed, but it is hoped that these initial studies in reasoning, imagery and imagination in autism will spark new studies, raise new criticisms, and ultimately lead to a fuller understanding of the disorder.

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APPENDICES

Appendix 1 - Experiment 1, Transitive Inference : Raw Data

Pairings in italics indicate *inferential* pairs. Other pairings are memory pairs.
Subject ages are measured in months.

Key: 1 = pass
0 = fail

AUTISM

			ROD PAIRING PRESENTED								
S	CA	VMA	*CE*	*AC*	BC	*AD*	*BD*	AB	*AE*	CD	*BE*
1	182	120	1	1	1	1	1	1	1	1	1
2	214	66	1	0	1	0	1	1	0	1	1
3	140	54	0	0	0	0	0	0	0	0	0
4	168	54	1	1	1	1	1	1	1	1	1
5	178	54	1	1	1	1	1	1	1	1	1
6	153	51	1	1	1	1	1	1	1	1	1
7	216	48	1	1	1	1	1	1	1	1	1
8	117	48	1	1	1	1	1	1	1	1	1
9	93	48	0	0	0	0	0	0	0	0	0
10	163	48	0	1	1	0	0	1	1	0	0
11	122	48	1	1	1	1	0	0	0	0	0
12	170	72	1	1	1	0	1	1	1	1	1
13	156	48	1	1	1	0	1	1	0	1	1
14	99	60	1	1	1	1	1	1	1	1	1
15	146	57	1	1	1	1	1	1	1	1	1
16	159	60	1	1	1	1	0	1	1	0	0
17	146	60	0	1	1	1	1	1	1	1	1

MENTAL HANDICAP

			ROD PAIRING PRESENTED								
S	CA	VMA	*CE*	*AC*	BC	*AD*	*BD*	AB	*AE*	CD	*BE*
18	104	60	1	1	1	1	1	1	1	1	0
19	110	48	1	1	1	1	1	1	1	1	1
20	113	60	1	1	1	1	1	1	1	1	1
21	127	51	1	1	1	1	1	1	1	1	1
22	143	57	1	1	1	1	1	1	1	1	1
23	188	57	1	1	1	1	1	1	1	1	1
24	179	60	1	1	1	1	1	1	1	1	1
25	218	57	1	0	1	1	0	1	0	1	0
26	132	60	1	1	1	1	1	1	1	1	1
27	121	51	1	1	1	1	0	1	1	1	0
28	149	60	1	1	1	1	1	1	1	1	1
29	177	48	0	0	0	0	0	0	0	0	0
30	102	48	1	1	1	1	1	1	1	1	1
31	144	51	1	0	1	0	0	1	0	1	0
32	178	48	0	1	1	1	0	1	0	0	0

NORMAL

		ROD PAIRING PRESENTED									
S	**CA**	***CE***	***AC***	**BC**	***AD***	***BD***	**AB**	***AE***	**CD**	***BE***	**DE**
33	58	1	1	1	1	1	1	1	1	1	1
34	57	1	1	1	1	1	1	1	1	1	1
35	58	1	1	1	0	0	1	1	1	0	1
36	59	0	0	1	1	0	1	0	1	1	1
37	58	1	1	1	1	1	1	1	1	1	1
38	57	1	1	1	1	1	1	1	1	1	1
39	57	1	1	1	1	1	1	1	1	1	1
40	58	1	1	1	1	1	1	1	1	1	1
41	59	1	1	1	1	1	1	1	1	1	1
42	59	1	1	1	1	1	1	1	1	1	1
43	57	1	1	1	1	1	1	1	1	1	1
44	58	1	1	1	1	1	1	1	1	1	1
45	58	1	1	1	1	1	1	1	1	1	1
46	57	1	1	1	1	1	1	1	1	1	1
47	59	1	1	1	1	1	1	1	1	1	1
48	58	1	1	1	1	1	1	1	1	1	1
49	58	1	1	1	1	1	1	1	1	1	1

Appendix 2 - Experiment 2, Analogical Reasoning Task - Causal Reasoning

Control Condition sequences and distractors.

The subject is presented with the first 3 pictures, and has to select the correct causal instrument, here listed fourth.

CAUSAL TERM	Sequences & (Distractors)
Cut:	Cut playdough: Cut apple: Cut bread: Knife (Hand dropping something; Rain wetting; Ball; Banana)
Break:	Broken egg: Broken lamp: Broken plate: Hand dropping something (Plug going in socket; Muddy field; Bottle; Torch)
Wet:	Wet car: Wet hair: Wet umbrella: Rain wetting (Matches; Knife; Fringing; Beard)
Burn:	Burning candle: Burning newspaper: Burning pan: Matches (Sun; Hand opening something; Paper bag; Book)
Open:	Open box: Open bottle: Open drawer: Hand opening something (Hand dropping something; Plug in socket; Vase; Can of pepsi)
Melt:	Melted chocolate: Melted snowman: Melted crayon: Sun (Knife; Muddy field; Scarecrow; Sledge)
Dirty:	Dirty dog: Dirty shorts: Dirty boots: Muddy field (Rain wetting; Matches; Toy dog; Pig)
Switch on:	T.V.on: Hairdryer on: Radio on: Plug going in socket (Hand opening something; Sun; Food mixer; Curling tongs)

Appendix 3 - Experiment 2, Analogical Reasoning Task - Analogy Condition sequences and distractors.

All have the general form a:b::c:d, with d hidden among 4 distractors.

Cut:	Playdough(A): Cut playdough(B):: Apple(C): Cut apple(D) Cut bread(E); Bruised apple(F); Ball(G); Banana(H)
Break:	Egg: Broken egg:: Lamp: Broken lamp Broken plate; Lamp switched on; Bottle; Torch
Wet:	Car: Wet car:: Hair: Wet hair Wet umbrella; Cut hair; Fringing; Beard
Burn:	Candle: Burning candle:: Newspaper: Burning newspaper Burning pan; Open newspaper; Paper bag; Book
Open:	Box: Open box:: Bottle: Open bottle Open drawer; Broken bottle; Vase; Can of pepsi
Melt:	Chocolate: Melted chocolate:: Snowman: Melted snowman Melted crayon; Dirty snowman; Scarecrow; Sledge
Dirty:	Shorts: Dirty shorts:: Dog: Dirty dog Dirty boots; Wet dog; Toy dog; Pig
Switch on:	T.V: T.V. on:: Hairdryer: Hairdryer on Radio on; Hairdryer burning; Food mixer on; Curling tongs

Appendix 4 - Experiment 2, Analogical Reasoning Task : Raw Data

Subject ages are measured in months.

Key (CRC): 1 = correct *causal* choice
0 = random distractor

Key (AR): D = correct analogical choice
E = right change, wrong object
F = right object, wrong change
G = perceptual similarity
H = semantic

AUTISM - Causal Reasoning Control Condition

			CAUSAL TERMS							
S	**CA**	**VMA**	**Cut**	**Break**	**Wet**	**Burn**	**Open**	**Melt**	**Dirty**	**Switch on**
1	182	120	1	1	1	1	1	1	1	1
2	214	66	1	1	1	1	1	1	1	1
3	140	54	0	0	0	1	0	0	0	0
4	168	54	1	1	1	1	1	1	1	1
5	178	54	1	1	1	1	1	0	1	0
6	153	51	1	1	1	1	1	1	1	1
7	216	48	1	1	1	1	0	1	0	1
8	117	48	1	1	1	1	1	1	1	1
9	93	48	1	1	1	1	1	1	1	0
10	163	48	1	0	1	1	1	1	1	1
11	122	48	1	1	1	1	1	1	1	1
12	170	72	1	0	1	0	1	1	1	1
13	156	48	1	1	1	1	1	0	1	1
14	99	60	1	1	1	1	1	1	1	1
15	146	57	1	0	1	0	1	0	1	1
16	159	60	1	1	1	1	1	0	1	1
17	146	60	1	1	1	1	1	1	1	1

AUTISM - Analogical Reasoning Condition

			ANALOGY TRIALS							
S	CA	VMA	Cut	Break	Wet	Burn	Open	Melt	Dirty	Switch on
1	182	120	D	F	D	D	D	H	D	H
2	214	66	D	D	D	D	D	D	D	D
3	140	54	E	H	H	E	E	G	G	F
4	168	54	D	D	D	D	D	D	D	D
5	178	54	F	D	F	D	D	F	D	F
6	153	51	F	D	D	D	D	F	F	D
7	216	48	F	D	D	F	D	F	D	D
8	117	48	D	D	F	D	F	D	D	F
9	93	48	F	F	D	F	F	D	D	D
10	163	48	F	F	F	D	H	E	G	D
11	122	48	F	F	D	D	D	D	F	D
12	170	72	F	F	D	D	D	D	F	D
13	156	48	D	F	F	F	D	F	D	D
14	99	60	F	F	D	F	D	F	F	D
15	146	57	F	D	D	D	D	D	F	D
16	159	60	D	D	D	H	D	F	D	F
17	146	60	F	F	F	D	D	H	H	H

MENTAL HANDICAP - Causal Reasoning Control Condition

			CAUSAL TERMS							
S	**CA**	**VMA**	**Cut**	**Break**	**Wet**	**Burn**	**Open**	**Melt**	**Dirty**	**Switch on**
18	104	60	1	1	1	1	1	1	1	1
19	110	48	1	1	1	1	1	1	1	1
20	113	60	1	1	1	1	1	1	1	1
21	127	52	1	1	1	1	1	1	1	1
22	143	57	1	1	1	1	1	1	1	1
23	188	57	1	1	1	1	1	1	1	1
24	179	60	1	1	1	1	1	1	1	1
25	218	57	1	1	1	1	1	1	1	1
26	132	60	1	1	1	0	1	0	1	0
27	121	51	1	1	1	1	1	0	1	1
28	149	60	1	1	1	1	1	1	1	1
29	177	48	1	1	1	1	1	1	1	1
30	102	48	1	1	1	1	1	1	1	1
31	144	51	1	1	1	1	1	1	1	1
32	178	48	1	1	1	1	1	1	1	1

MENTAL HANDICAP - Analogical Reasoning Condition

			ANALOGY TRIALS							
S	**CA**	**VMA**	**Cut**	**Break**	**Wet**	**Burn**	**Open**	**Melt**	**Dirty**	**Switch on**
18	104	60	D	F	D	D	D	F	D	D
19	110	48	D	D	D	D	D	D	D	D
20	113	60	F	E	E	F	D	D	H	E
21	127	51	F	D	D	D	D	D	D	D
22	143	57	D	D	D	D	D	D	D	D
23	188	57	D	D	D	F	D	F	D	D
24	179	60	D	D	D	D	D	D	D	D
25	218	57	D	D	D	D	D	D	D	D
26	132	60	D	D	D	D	D	D	D	F
27	121	51	D	D	D	E	D	D	G	G
28	149	60	D	D	D	F	D	D	D	F
29	177	48	F	D	D	H	F	G	H	E
30	102	48	D	D	D	D	D	D	D	D
31	144	51	D	D	D	D	D	D	D	D
32	178	48	E	D	D	D	F	D	F	D

NORMAL - Causal Reasoning Control Condition

		CAUSAL TERMS							
S	**CA**	**Cut**	**Break**	**Wet**	**Burn**	**Open**	**Melt**	**Dirty**	**Switch on**
33	58	1	1	1	1	1	1	1	1
34	57	1	1	1	1	1	1	1	1
35	58	1	1	1	1	1	1	1	1
36	59	1	1	1	1	1	1	1	1
37	58	1	1	1	1	1	1	1	1
38	57	1	1	1	1	1	1	1	1
39	57	1	1	1	1	1	1	1	1
40	58	1	1	1	1	1	1	1	1
41	59	1	1	1	1	1	1	1	1
42	59	1	1	1	1	1	1	1	1
43	57	1	1	1	1	1	1	1	1
44	58	1	1	1	1	1	1	1	1
45	58	1	1	1	1	1	1	1	1
46	57	1	1	1	1	1	1	1	1
47	59	1	1	1	1	1	1	1	1
48	58	1	1	1	1	1	1	1	1
49	58	1	1	1	1	1	1	1	1

NORMAL - Analogical Reasoning Condition

		ANALOGY TRIALS							
S	**CA**	**Cut**	**Break**	**Wet**	**Burn**	**Open**	**Melt**	**Dirty**	**Switch on**
33	58	D	D	D	D	D	D	D	D
34	57	D	D	D	D	D	E	F	D
35	58	D	D	D	D	D	E	D	D
36	59	D	D	D	D	D	D	D	D
37	58	E	E	D	E	D	D	F	E
38	57	D	D	D	D	D	D	F	D
39	57	D	D	D	D	D	D	D	D
40	58	D	D	D	D	D	F	D	D
41	59	D	D	D	D	D	D	D	D
42	59	D	D	D	D	D	D	D	D
43	57	D	D	D	F	D	F	D	D
44	58	D	D	D	D	D	D	D	D
45	58	D	D	D	D	D	D	D	D
46	57	D	D	D	D	D	D	D	D
47	59	F	F	D	F	D	F	D	F
48	58	E	D	E	F	D	E	D	D
49	58	D	D	D	D	D	D	D	D

Appendix 5 - Experiment 3, Counterfactual Syllogistic Reasoning Task - Reality Control (Probe) Questions.

What noise do cows make?

What colour are bananas?

Where do fish live?

What temperature is ice/ How does it feel?

What colour is milk?

What noise do cats make?

What are books made of?

What colour is snow?

How do birds move?

What colour is blood?

Appendix 6 - Experiment 3, Counterfactual Syllogistic Reasoning Task -Verbal Only Condition Premises.

Method of presentation: I have a story where...

All cows go "Quack" (Premise 1)

Freda is a cow (Premise 2)

In my story...

Does Freda say "Quack"? (Conclusion Question)

(p1) All bananas are pink

(p2) John is eating a banana

(c) Is the banana pink?

(p1) All fish live in trees

(p2) Tot is a fish

(c) Does Tot live up a tree?

(p1) All ice is hot

(p2) Anne has some ice

(c) Is the ice hot?

(p1) All milk is green

(p2) James is drinking some milk

(c) Is the milk green?

Appendix 7 - **Experiment 3, Counterfactual Syllogistic Reasoning Task - Verbal Plus Imagery Condition Premises.**

Method of presentation: I have a story where...

All cats bark (Premise 1)

Rex is a cat (Premise 2)

In my story...

Does Rex bark? (Conclusion Question)

(p1) All books are made of grass

(p2) Andrew is looking at a book

(c) Is the book made of grass?

(p1) All snow is black

(p2) Tom touches some snow

(c) Is the snow black?

(p1) All birds swim

(p2) Pepi is a bird

(c) Does Pepi swim?

(p1) All blood is blue

(p2) Mary has cut her finger

(c) Is the blood blue?

Appendix 8 - **Experiment 3, Counterfactual Reasoning Experiment: Raw Data**

Key: P = passed all questions
1 = pass
0 = fail

CA and VMA are measured in months.

N.B.: Subject data that is missing is due to the subject being absent during the particular test session. Analyses were conducted to allow for this.

AUTISM

VERBAL ONLY								
S	**CA**	**VMA**	**Probe**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
1	182	120	P	1	1	1	1	1
2	214	66	P	0	0	0	0	0
3	140	54	P	1	1	1	1	1
4	168	54	P	1	1	1	1	1
5	178	54	P	1	1	1	1	1
6	153	51	P	1	1	1	1	0
7	216	48	P	1	1	1	1	1
8	117	48	P	0	0	1	1	0
9	93	48	P	1	1	1	1	1
10	163	48	P	1	1	0	0	0
11	122	48	P	1	1	1	1	1
12	170	72	P	1	1	1	1	1
13	156	48	P	1	1	1	1	1
14	99	60	P	1	1	1	1	1
15	146	57	P	1	1	1	1	1
16	159	60	P	1	1	1	1	1
17	146	60	P	0	0	0	0	0

AUTISM

VERBAL + IMAGERY								
S	CA	VMA	Probe	Q1	Q2	Q3	Q4	Q5
1	182	120	P	1	1	1	1	1
2	214	66	P	0	0	0	0	0
4	168	54	P	0	0	0	0	1
5	178	54	P	1	1	1	1	1
6	153	51	P	1	1	1	1	1
7	216	48	P	0	0	0	0	0
8	117	48	P	1	0	1	0	0
9	93	48	P	0	0	0	0	0
10	163	48	P	1	1	0	0	0
11	122	48	P	0	0	1	1	1
12	170	72	P	1	1	1	1	1
13	156	48	P	1	1	1	1	1
14	99	60	P	1	1	1	1	1
15	146	57	P	0	0	0	0	0
16	159	60	P	0	0	0	0	1
17	146	60	P	0	0	0	0	0

MENTAL HANDICAP

VERBAL ONLY								
S	CA	VMA	Probe	Q1	Q2	Q3	Q4	Q5
18	104	60	P	1	1	1	1	0
19	110	48	P	1	1	1	0	0
20	113	60	P	0	0	0	0	0
21	127	51	P	0	0	0	0	0
22	143	57	P	0	0	0	0	0
23	188	57	P	0	0	0	0	0
24	179	60	P	1	1	1	1	1
25	218	57	P	1	1	1	1	0
26	132	60	P	1	1	1	1	1
27	121	51	P	0	0	0	0	0
28	149	60	P	1	1	1	1	1
29	177	48	P	0	0	0	0	0
30	102	48	P	0	0	0	0	0
31	144	51	P	0	0	0	0	1
32	178	48	P	0	0	0	0	0

VERBAL + IMAGERY								
S	CA	VMA	Probe	Q1	Q2	Q3	Q4	Q5
18	104	60	P	0	0	0	0	0
19	110	48	P	1	1	1	1	0
20	113	60	P	1	1	1	1	0
21	127	51	P	1	1	1	1	0
22	143	57	P	1	1	1	0	0
23	188	57	P	0	0	0	0	0
24	179	60	P	1	1	1	1	1
25	218	57	P	0	1	1	1	1
27	121	51	P	1	1	1	1	0
28	149	60	P	1	1	1	1	1
29	177	48	P	0	0	0	0	0
30	102	48	P	0	0	0	0	0
31	144	51	P	1	1	1	1	1
32	178	48	P	0	0	0	0	0

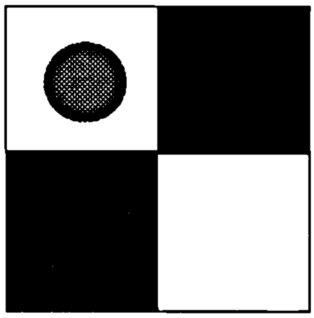
NORMAL

VERBAL ONLY							
S	CA	Probe	Q1	Q2	Q3	Q4	Q5
33	58	P	1	0	0	1	1
34	57	P	1	0	0	0	1
35	58	P	1	0	0	0	1
36	59	P	1	1	1	1	1
37	58	P	1	1	0	0	0
38	57	P	1	0	0	1	1
39	57	P	0	0	0	0	0
40	58	P	1	1	1	1	1
41	59	P	1	1	1	1	1
42	59	P	1	1	1	1	1
43	57	P	0	0	0	0	0
44	58	P	0	0	0	0	0
45	58	P	0	0	0	0	0
46	57	P	1	1	1	1	1
47	59	P	0	0	0	0	0
48	58	P	0	0	0	0	0
49	58	P	0	0	0	0	0

NORMAL

VERBAL + IMAGERY							
S	**CA**	**Probe**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
33	58	P	0	1	1	0	1
34	57	P	0	0	1	1	0
35	58	P	1	1	1	1	0
37	58	P	0	0	0	0	0
38	57	P	1	1	1	1	1
39	57	P	1	1	1	1	0
40	58	P	1	1	1	1	1
41	59	P	1	1	1	1	1
42	59	P	1	0	1	0	0
43	57	P	0	0	0	0	0
44	58	P	1	1	1	1	0
45	58	P	1	0	1	1	1
46	57	P	1	0	1	1	1
47	59	P	1	1	1	1	1
48	58	P	0	1	1	0	0

Appendix 9 - **Experiment 4, "Chessboard" visual memory experiment. Example of 2x2 board, depicting draught's piece in place.**



Appendix 10 - Experiment 4 - "Chessboard" visual memory: Raw Data

Subject ages are measured in months.

Key: 1 = passed stage
0 = failed stage

AUTISM

			STAGE COMPLETED					
S	CA	VMA	2x2	3x3	4x4	Full board (1 draught)	Full board (2 draughts)	Full board (3 draughts)
1	176	57	1	0	0	0	0	0
2	152	48	1	0	0	0	0	0
3	168	69	1	0	0	0	0	0
4	145	66	1	1	1	1	1	0
5	156	66	1	0	0	0	0	0
6	168	54	1	0	0	0	0	0
7	121	48	1	0	0	0	0	0
8	152	54	1	0	0	0	0	0
9	190	54	1	0	0	0	0	0
10	177	57	1	1	1	1	0	0
11	129	48	1	1	1	1	1	1
12	105	48	1	0	0	0	0	0
13	175	48	1	1	1	1	1	1
14	134	48	1	0	0	0	0	0
15	194	120	1	0	0	0	0	0

MENTAL HANDICAP

			STAGE COMPLETED					
S	CA	VMA	2x2	3x3	4x4	Full board (1 draught)	Full board (2 draughts)	Full board (3 draughts)
16	139	51	1	1	1	1	0	0
17	122	48	1	0	0	0	0	0
18	125	60	1	1	1	1	1	0
19	116	60	1	0	0	0	0	0
20	155	57	1	0	0	0	0	0
21	200	57	1	1	1	1	0	0
22	191	60	1	0	0	0	0	0
23	144	60	1	0	0	0	0	0
24	132	51	1	0	0	0	0	0
25	162	60	1	1	1	1	0	0
26	189	48	1	0	0	0	0	0
27	114	48	1	0	0	0	0	0
28	156	51	1	0	0	0	0	0
29	190	48	1	0	0	0	0	0

NORMAL

		STAGE COMPLETED					
S	CA	2x2	3x3	4x4	Full board (1 draught)	Full board (2 draughts)	Full board (3 draughts)
30	60	1	0	0	0	0	0
31	60	1	1	1	1	0	0
32	60	1	0	0	0	0	0
33	59	1	1	1	1	1	0
34	58	1	1	1	1	0	0
35	58	1	1	1	0	0	0
36	60	1	1	1	1	0	0
37	60	1	1	1	1	0	0
38	59	1	0	0	0	0	0
39	59	1	1	1	1	0	0
40	58	1	1	0	0	0	0
41	58	1	1	1	0	0	0
42	58	1	1	0	0	0	0
43	58	1	0	0	0	0	0
44	58	0	0	0	0	0	0

<u>Appendix 11</u> - Experiment 5 - "Complex Pictures" visual memory task: Raw Data

Subject ages measured in months.

<u>AUTISM</u>

			ITEMS RECALLED FOR EACH CONDITION			
S	**CA**	**VMA**	**No.Items (Mem)**	**No. Specifics**	**No. Items (Story)**	**No. Specifics**
1	176	57	4	2	2	0
2	152	48	0	0	0	0
3	168	69	2	1	3	2
4	145	66	1	0	6	0
5	156	66	7	3	5	2
6	168	54	2	0	4	1
7	121	48	7	3	2	0
8	152	54	4	1	2	0
9	190	54	0	0	0	0
10	177	57	2	0	4	1
11	129	48	1	0	0	0
12	105	48	1	0	1	0
13	175	48	1	0	2	0
14	134	48	1	0	0	0
15	194	120	2	0	2	0

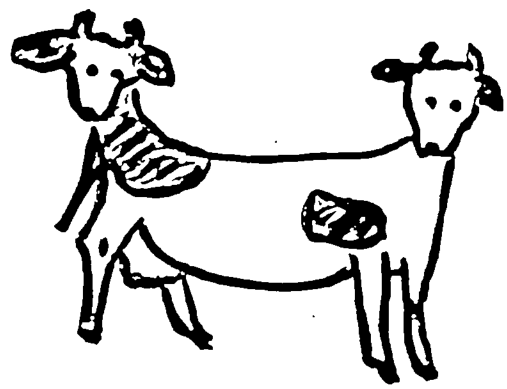
MENTAL HANDICAP

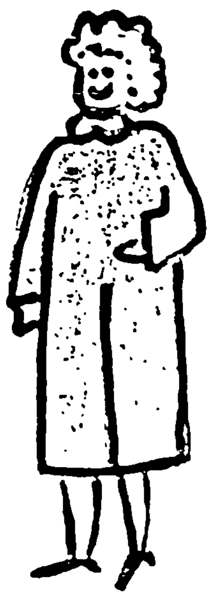
			ITEMS RECALLED FOR EACH CONDITION			
S	**CA**	**VMA**	**No.Items (Mem)**	**No. Specifics**	**No. Items (Story)**	**No. Specifics**
16	139	51	5	1	2	0
17	122	48	4	2	4	1
18	125	60	2	0	2	0
19	116	60	2	1	4	1
20	155	57	4	2	4	1
21	200	57	4	2	3	0
22	191	60	3	0	3	1
23	144	60	2	0	2	0
24	132	51	2	1	2	0
25	162	60	3	1	3	0
26	189	48	0	0	0	0
27	114	48	1	0	1	0
28	156	51	2	1	6	2
29	190	48	3	1	2	0

NORMAL

		ITEMS RECALLED FOR EACH CONDITION			
S	CA	No. Items (Mem)	No. Specifics	No. Items (Story)	No. Specifics
30	60	1	0	4	2
31	60	3	0	3	2
32	60	5	4	4	3
33	59	4	3	2	2
34	58	5	3	3	1
35	58	6	4	5	3
36	60	5	3	2	1
37	60	5	3	0	0
38	59	3	0	5	3
39	59	6	4	7	4
40	58	4	3	6	3
41	58	5	3	5	3
42	58	5	3	5	4
43	58	5	2	3	2
44	58	5	3	6	6

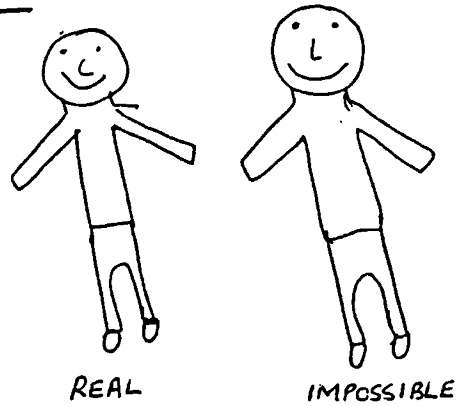
Appendix 12 - Experiment 6, Drawings task (real versus impossible): examples of the Control Question Stimuli (Instruction - "Show me the impossible (x), the (x) that does not exist").

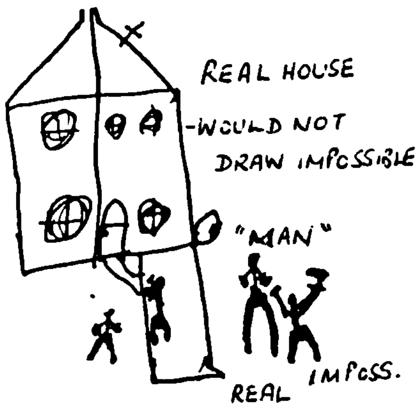


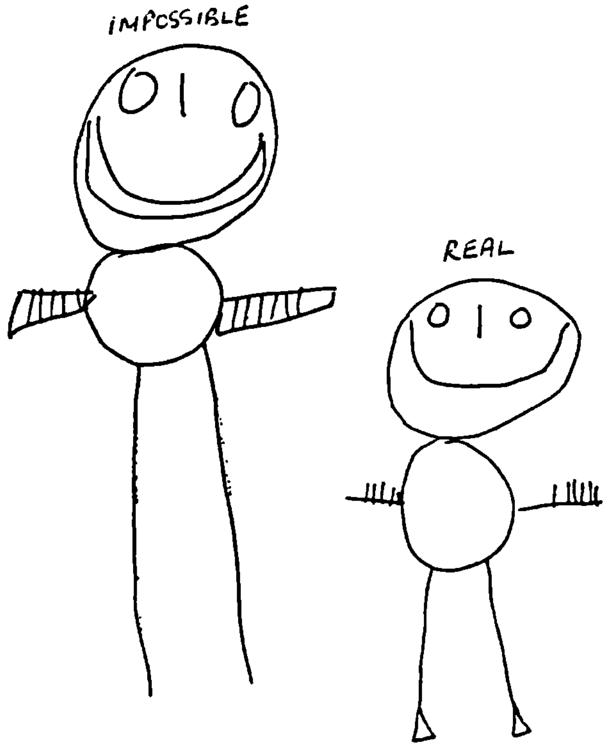


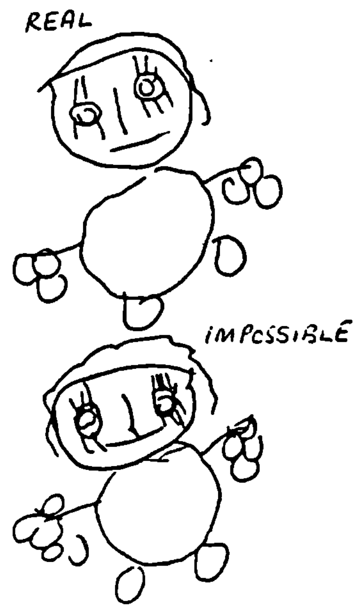
Appendix 13 - **Experiment 6, Drawings task (real versus impossible): examples of drawings produced by each subject group.**

AUTISM



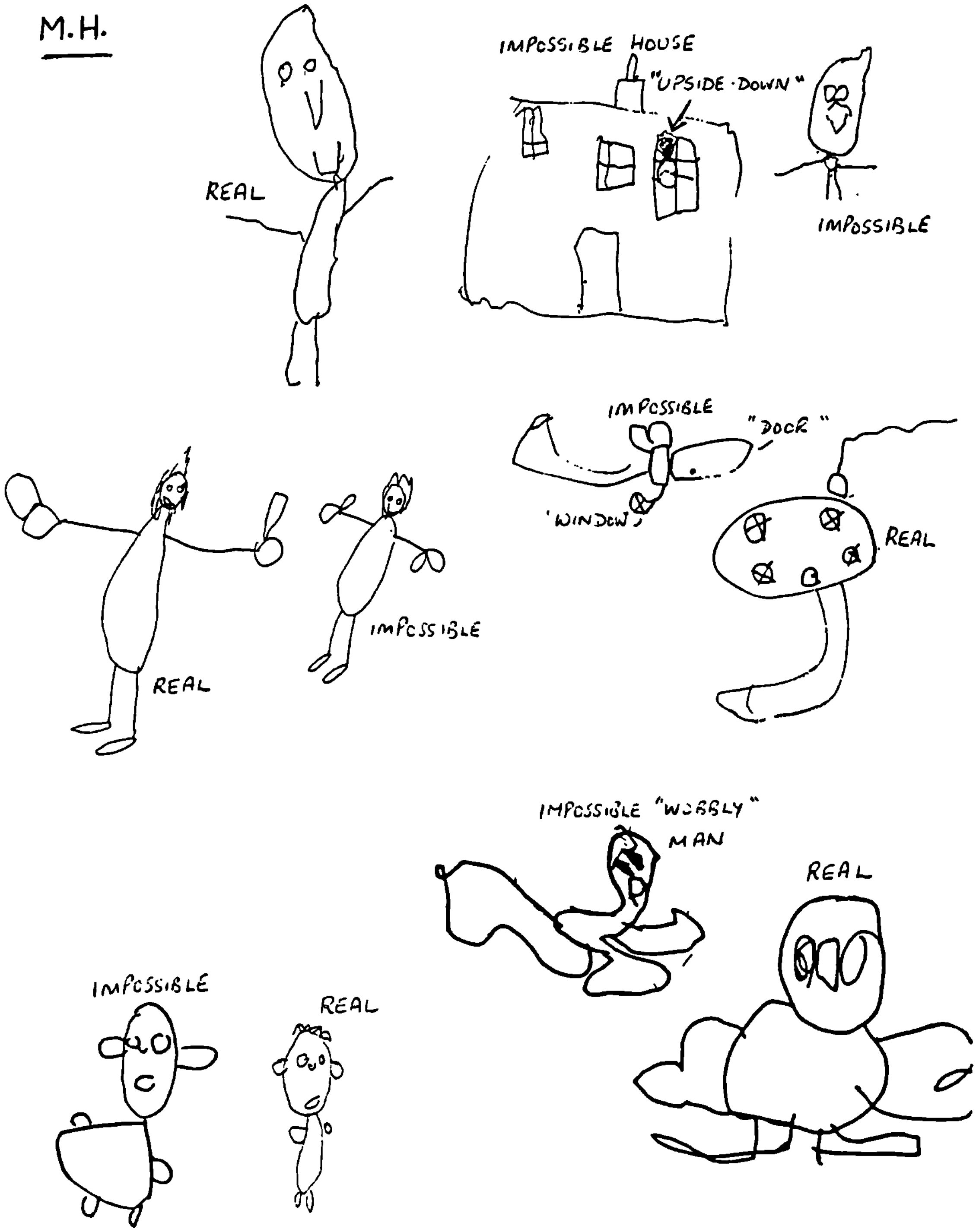




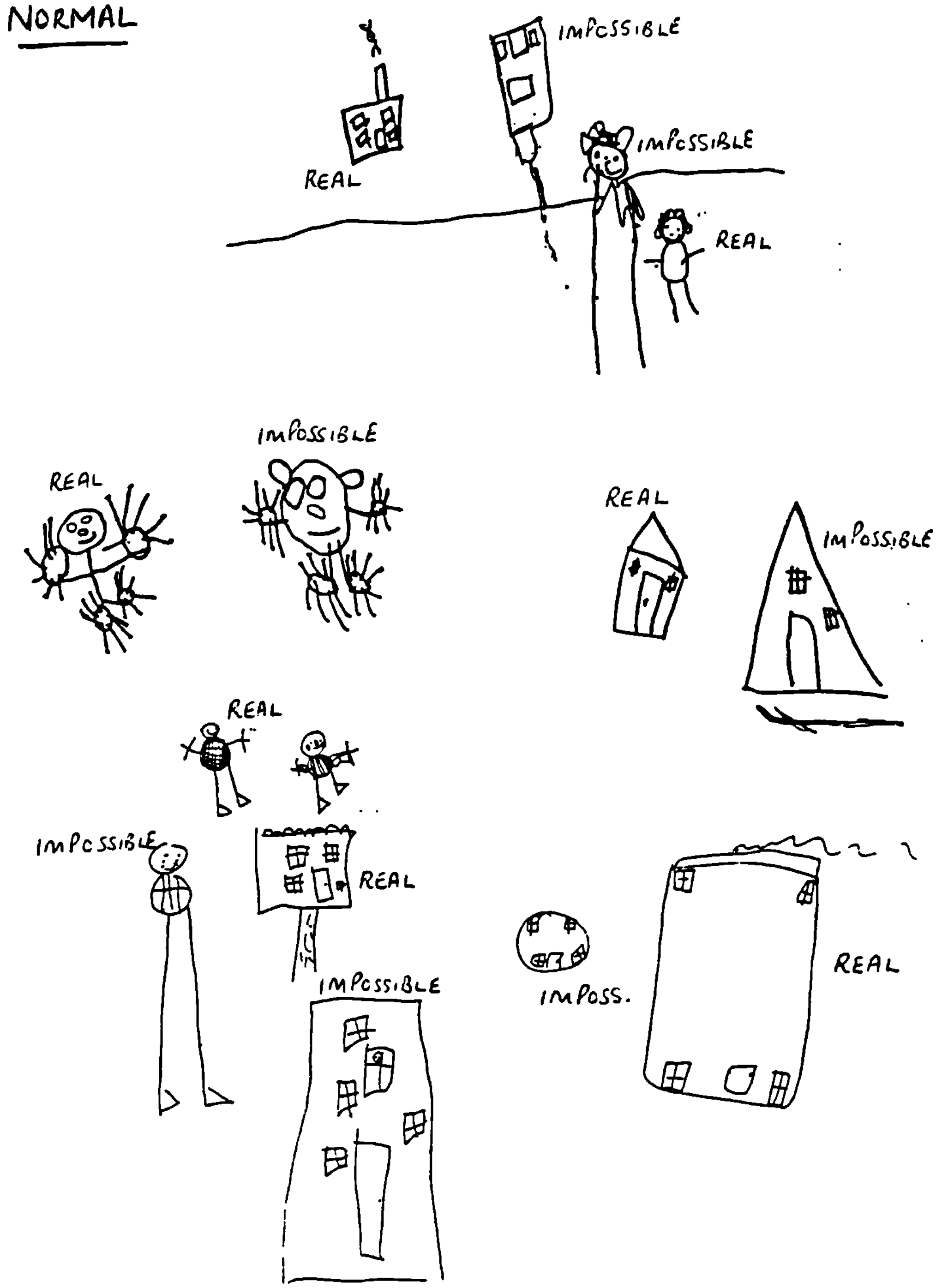


Appendix 13 - **Experiment 6, Drawings task (real versus impossible): examples of drawings produced by each subject group.**

M.H.

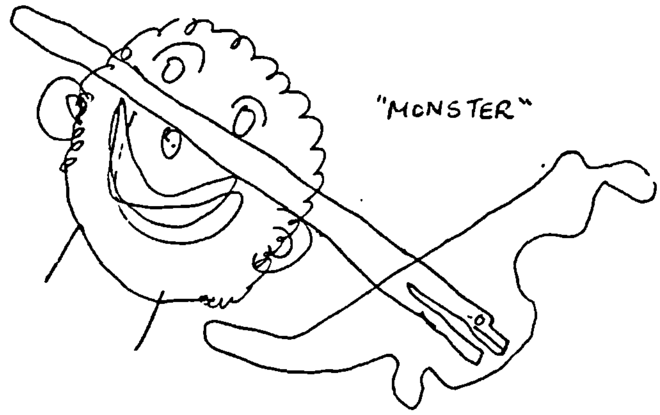


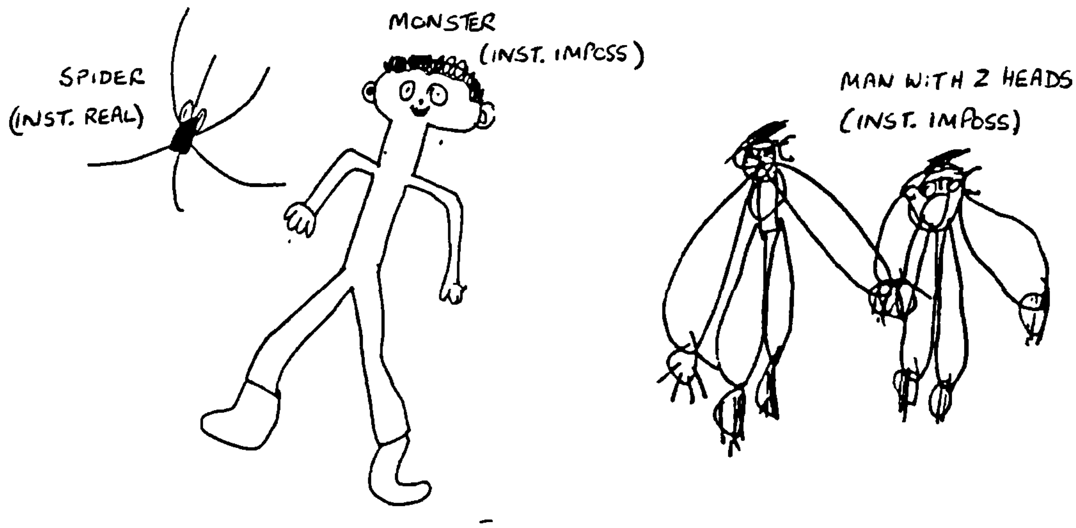
Appendix 13 - **Experiment 6, Drawings task (real versus impossible): examples of drawings produced by each subject group.**

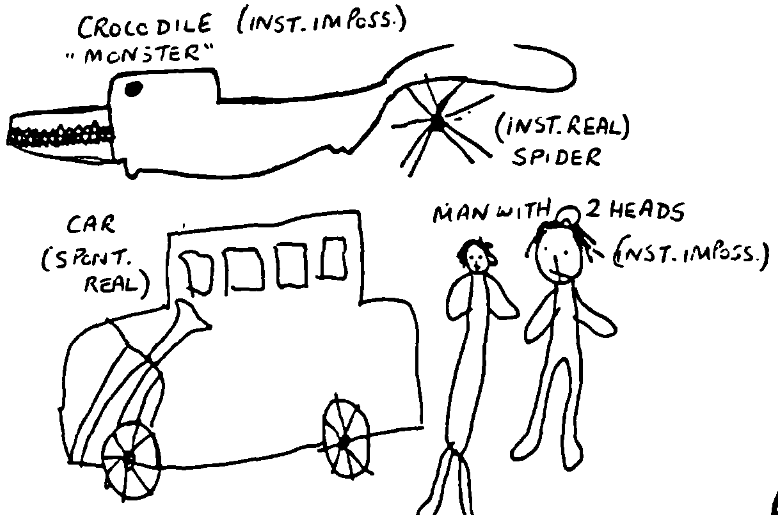


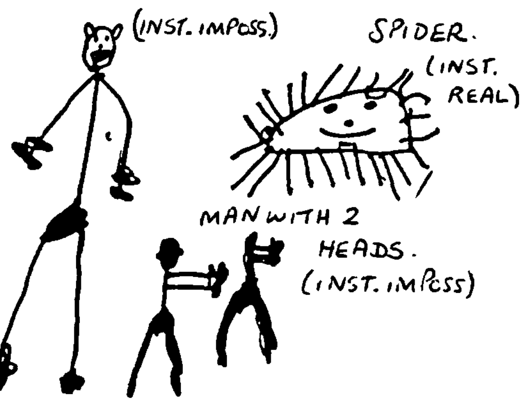
Appendix 14 - **Experiment 7, Drawings task (spontaneous versus instructed): examples of drawings produced by each subject group.**

AUTISM



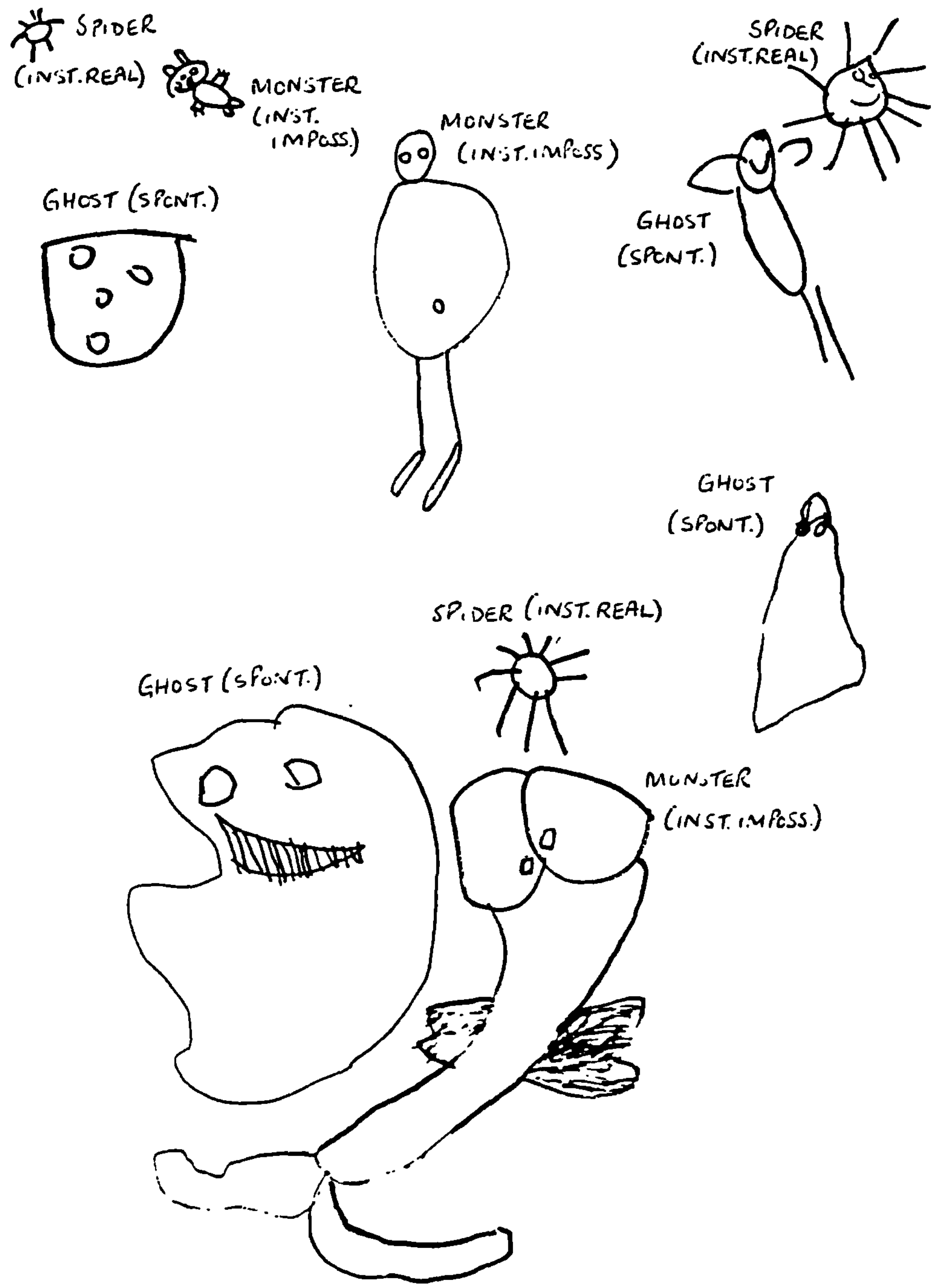




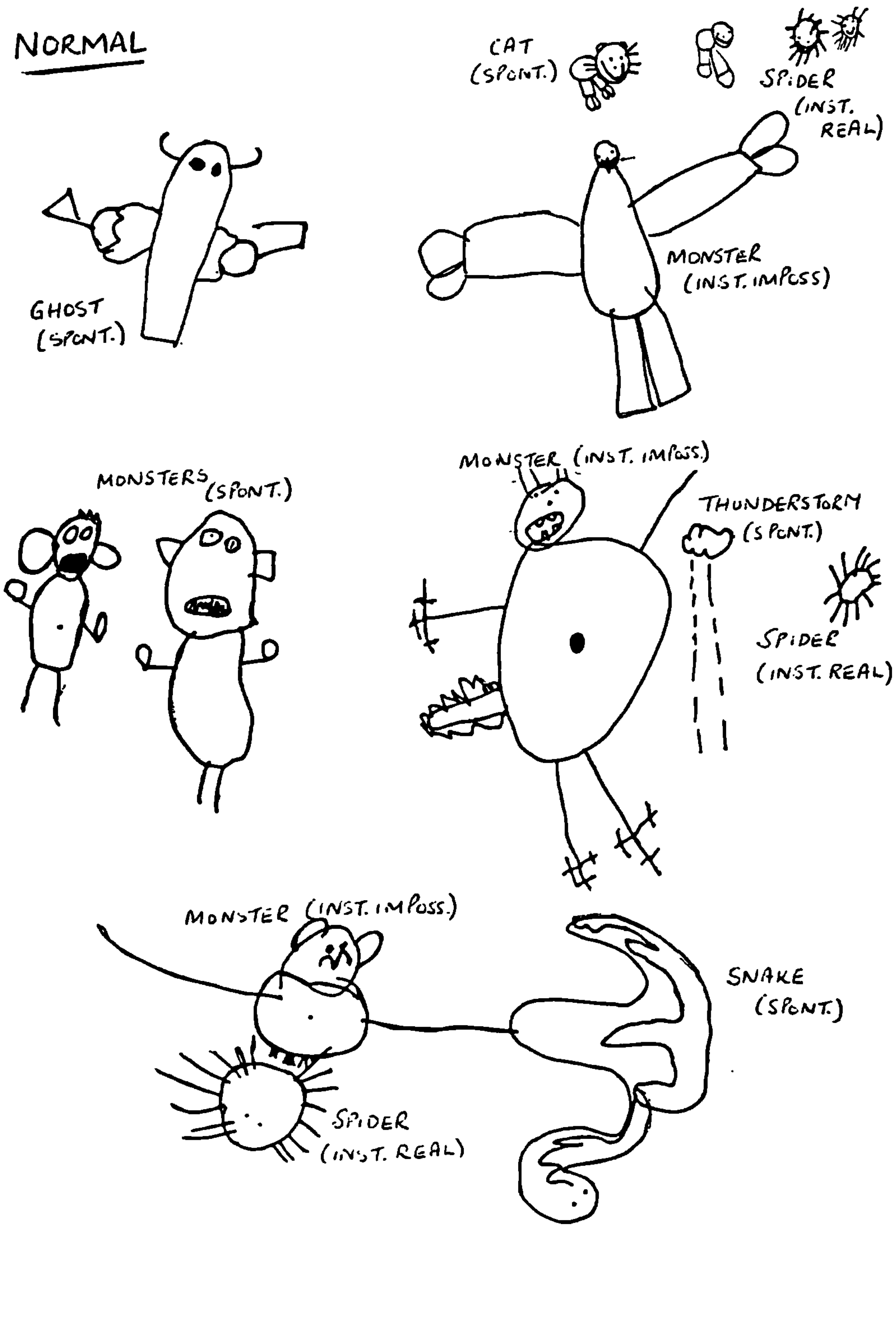


Appendix 14 - **Experiment 7, Drawings task (spontaneous versus instructed): examples of drawings produced by each subject group.**

M.H.



Appendix 14 - **Experiment 7, Drawings task (spontaneous versus instructed): examples of drawings produced by each subject group.**



Appendix 15 - Experiment 8, Generativity task: Raw Data

Subject ages are measured in months.

NB. Scores show only those items which correctly matched criteria (e.g., beginning with correct sound for Verbal Fluency Task)

AUTISM

			NO. OF ITEMS GENERATED	
S	CA	VMA	Brick Task	Verbal Fluency
1	176	57	0	1
2	152	48	4	0
3	168	69	1	1
4	145	66	2	0
5	156	66	5	1
6	168	54	3	1
7	121	48	5	1
8	152	54	2	2
9	190	54	2	1
10	177	57	2	1
11	129	48	4	0
12	105	48	1	5
13	175	48	1	2
14	134	48	3	1
15	194	120	2	1

MENTAL HANDICAP

			NO. OF ITEMS GENERATED	
S	CA	VMA	Brick	Verbal Fluency
16	139	51	4	1
17	122	48	3	2
18	125	60	3	4
19	116	60	2	0
20	155	57	5	1
21	200	57	2	2
22	191	60	2	1
23	144	60	4	0
24	132	51	1	1
25	162	60	2	1
26	189	48	3	1
27	114	48	1	2
28	156	51	2	1
29	190	48	2	2

NORMAL

		NO. OF ITEMS GENERATED	
S	CA	Brick	Verbal Fluency
30	60	3	3
31	60	4	6
32	60	2	0
33	59	6	4
34	58	3	1
35	58	6	1
36	60	4	3
37	60	4	4
38	59	6	3
39	59	4	1
40	58	2	4
41	58	3	3
42	58	5	3
43	58	1	3
44	58	3	0